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March 18, 2005

Mr. Galen Buller
Water Division Director
City of Santa Fe
801 W. San Mateo
Santa Fe, New Mexico 87505

Subject: MRC WTP Water Quality Studies and Evaluations Report
Final Report Volume 1

Dear Mr. Buller:

CDM is pleased to present the City with the *MRC WTP Water Qualities Studies and Evaluations Report – Volume 1*. This volume includes summaries of the water quality studies, comparisons of the treatment options, recommendations on processes and facilities, and estimated construction and O&M costs.

We wish to acknowledge the valuable assistance the City's staff has provided in completing this project. In particular, we would like to thank the Canyon Road WTP staff for their help in obtaining samples, providing water quality data, and assisting in testing.

We look forward to working with the City and County on this important facility.

Sincerely,

Mark D. Ryan

Mark D. Ryan, P.E.
Project Manager
Camp Dresser & McKee Inc.

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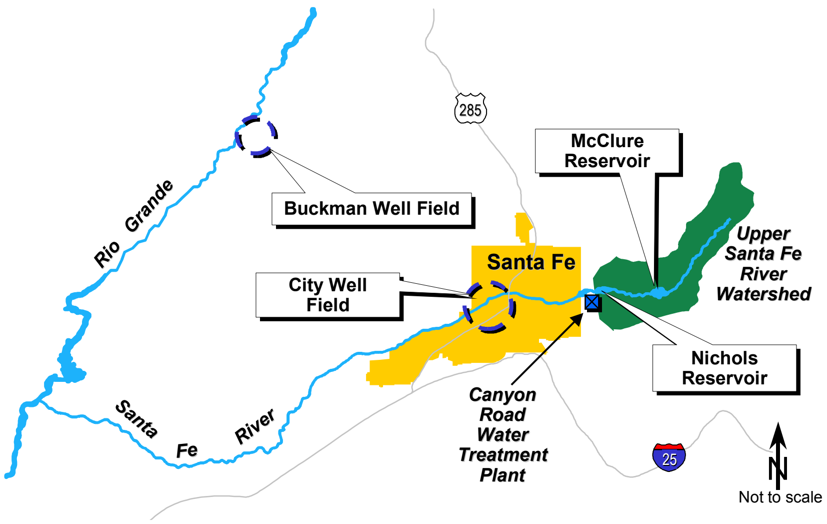
Executive Summary

Background

The City of Santa Fe, Santa Fe County and Las Campanas are currently cooperating on the Buckman Direct Diversion Project to utilize San Juan-Chama Project water stored in northern New Mexico and delivered to the area via the Rio Grande. This project will provide 6,930 acre feet of water per year (AFY) to the City and County. As part of the Buckman Direct Diversion Project, Rio Grande water will be diverted through a side-channel diversion structure, pumped to a sedimentation facility near the river, and then conveyed through a pipeline and two booster stations to a new Water Treatment Plant (WTP). The new plant will be located at the north end of the Municipal Recreation Complex (MRC) along Caja del Rio Road, south of Las Campanas. It will have a peak treatment capacity of 15 million gallons per day (MGD) and an average flow rate of 6.2 MGD.



Santa Fe's Existing Sources of Water Supply

Extensive water quality data has been collected on the Rio Grande just north of the proposed diversion location. This data was supplemented with additional water quality samples collected for laboratory analysis under this study to determine treatment implications. This data indicates that the water quality varies significantly throughout the year, the solids content and turbidity is very high during some seasons, the temperature fluctuates over the year, and there are some metal constituents. Data also indicates that the alkalinity, pH and organic content vary over the course of the year. This wide fluctuation in raw water characteristics dictates the need for a robust and flexible water treatment plant.

Water quality information and test results were evaluated to determine treatment requirements, identify process alternatives, and provide a basis for cost estimating. This report provides:

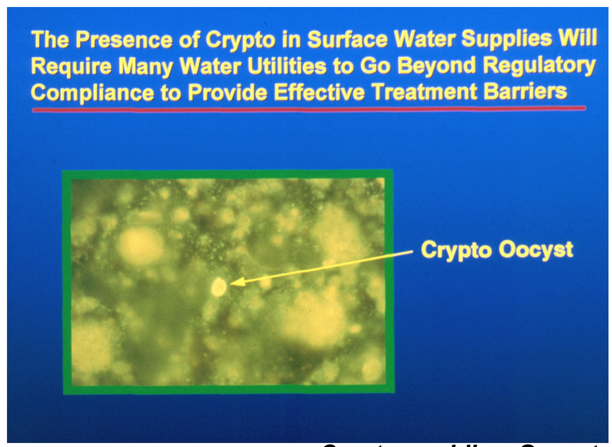
- Testing and analysis results
- Regulatory and process requirements
- Process alternatives and analysis through comparison

- Conclusions and recommended treatment options
- Estimated construction and annual operation and maintenance costs
- Recommendations for additional studies

Testing Results, Requirements and Process Alternatives

The testing conducted in this study is documented in nine technical memoranda, which are included in Volume 2. Based on an evaluation of testing results and the applicable regulatory requirements, treatment implications and process alternatives were developed and are provided in Section 2 of the report. Each of the nine technical memoranda and treatment implications are summarized below.

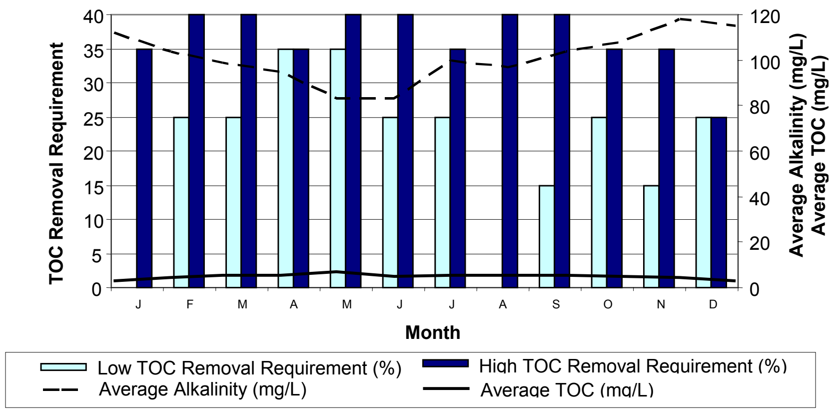
***Cryptosporidium* and Microbiological Study** - Seven samples were collected from the Rio Grande. *Cryptosporidium* was detected in only one of the samples and the EPA methodology of data analysis would place the site in Bin Classification 1 - requiring no additional treatment above standard filtration that meets turbidity provisions. However, as only seven samples were collected rather than the 24 required for EPA Bin Classification, design of the MRC WTP for Bin Classification 2 (1-log additional *Cryptosporidium* removal) was recommended. Process alternatives found to be potentially applicable to the MRC WTP included presedimentation with coagulation, lower finished water turbidity, membranes, chlorine dioxide, ozone, and UV.



***Cryptosporidium* Oocyst**

Taste and Odor Study - Samples were collected during three testing periods. Data from the Otowi Gaging Station was also evaluated. Odor constituents were not detected during sampling but may be an occasional concern based upon historic data. Taste constituents were present in all three testing periods with iron and manganese the most likely culprits. However, natural organic matter (NOM), synthetic organic contaminants (SOCs), and algae could potentially contribute to taste complaints, although these were not detected. Most constituents are either unregulated or regulated only as an unenforceable secondary standard. Treatment options that address taste and odor causing compounds include the use of permanganate, ozone, chlorine dioxide, sodium hydroxide, dissolved air flotation, copper sulfate, enhanced coagulation/sedimentation/filtration, powdered activated carbon (PAC), granular activated carbon (GAC) filters or contactors, and biologically active filters.

Contaminants Study - Samples from the Rio Grande were collected during three testing periods. Samples from four Buckman Wells and a booster station were collected during the final testing period. The results of the testing and the historic water quality data evaluation revealed that only a few contaminants are present in the Rio Grande near or above their regulatory limit including turbidity, color, aluminum, iron, manganese, and nitrate. Arsenic and uranium were identified as problematic in the wells. Process alternatives were identified for these constituents. The potentially applicable alternatives include enhanced coagulation/sedimentation/filtration, permanganate, chlorine dioxide, ozone, presedimentation, conventional coagulation/sedimentation/filtration and membranes.



TOC Removal Required Based on USGS Otowi Water Quality Data

Organics and TOC Evaluation - Raw water quality was sampled during three rounds of testing. The results of the testing and the historic data indicate that Total Organic Carbon (TOC) ranges from 1.1 to 9.6 mg/L. Based upon the range of alkalinity, the TOC removal requirements in some months will be as high as 40 percent. The figure above is a graphical display of potential TOC removal requirements by month based upon the historic data. A TOC removal goal of 42 percent was recommended. Bench-scale testing indicated that coagulation/sedimentation will remove a substantial portion of the TOC. The removal requirements were nearly met or exceeded during two rounds although the chemical doses were optimized only for turbidity removal and not TOC removal. Process alternatives that could satisfactorily remove certain percentages of TOC were identified. The retained alternatives included enhanced coagulation/sedimentation/filtration, biologically active filters with anthracite or GAC, dissolved air floatation, membranes, magnetic ion exchange (MIEX), GAC contactors, and PAC.

Chemical Dose Optimization and Evaluation - Bench scale testing was conducted during each of three testing periods on water collected from the Rio Grande. Equipment at the Canyon Road WTP was utilized and is pictured to the right.

Canyon Road WTP Bench Scale Testing Equipment

Testing was used to evaluate the effectiveness of three coagulants, the necessity or usefulness of coagulant aid and flocculent aid polymers, and the ability of various pre-oxidants to improve settled water quality. Testing also evaluated mixing energy, polymer feed timing and order, and pH adjustment effects. The ranges of optimized chemical doses from the three periods are shown in the table below.

Range of Optimized Chemical Doses[1]

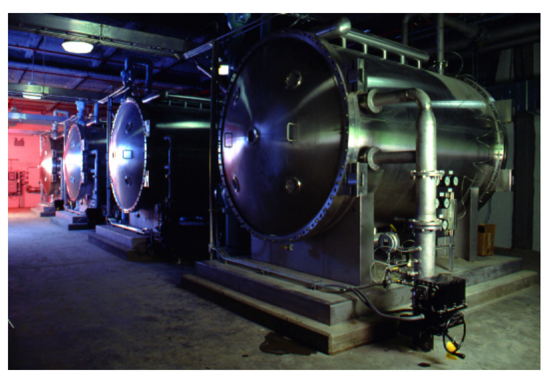
Chemical	Dose Range, mg/L
Pre-Oxidant	0.5 – 1.0
Alum	14 – 30
Ferric Chloride	7 – 35
PACl	3 – 4 [2]
Coagulant Aid	0.5 – 2.0
Flocculant Aid	0.25 – 0.5

[1]Chemical doses were optimized for turbidity removal but not for TOC removal.
[2]The potential high end dose was not determined as the testing during the first round was unsuccessful.

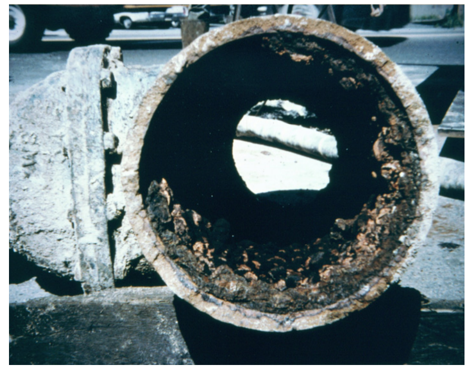
The testing indicated all three coagulants worked satisfactorily but ferric chloride worked slightly better than alum. The testing also showed the use of polymers as coagulant aids and flocculant aids improved the test results dramatically and that a preoxidant improved flocculation. Tapered flocculation resulted in better water quality than constant speed flocculation. All identified coagulants were initially deemed applicable to the MRC WTP: ferric chloride, ferric sulfate, alum, acidified alum, PACl and dual coagulants. The applicable preoxidants were permanganate, ozone and chlorine dioxide.

Alum Storage in Oshkosh, WI

Disinfection/Disinfection By-Products Study - Demand and decay testing for sodium hypochlorite, chlorine dioxide, and ozone was conducted during the first testing round. The concentration of disinfection by-products (DBPs) was also determined. High DBP formation (concentrations were above regulatory limits) occurred but this was likely the result of insufficient TOC removal during bench scale testing of the samples. Design goals for total trihalomethanes (TTHMs) and haloacetic acids (HAA) were recommended as 64 and 48 µg/L, respectively. The inactivation requirements for *Giardia*, viruses and *Cryptosporidium* were identified. Sodium hypochlorite, ozone and UV were selected as applicable alternatives for primary disinfection. Only sodium hypochlorite was carried forward as appropriate for secondary disinfection to meet chlorine residual requirements.


Ozone Generators Used for Disinfection

Corrosion and Blending Study - Corrosion and blending analyses were completed using an equilibrium chemistry model. Other communities have experienced severe problems when introducing and blending new water sources not properly conditioned for compatibility with the existing sources. Five separate scenarios were modeled to evaluate corrosion and blending concerns as the water quality and the operation and management of the Buckman Direct Diversion and the existing Buckman wells change throughout the year. Conclusions and recommendations were that the pH of the treated water from the MRC WTP is necessary to match the Buckman Well water, which could be accomplished by the addition of sodium hydroxide or soda ash and monitoring of pH in the system will be necessary to adequately evaluate blending operations.

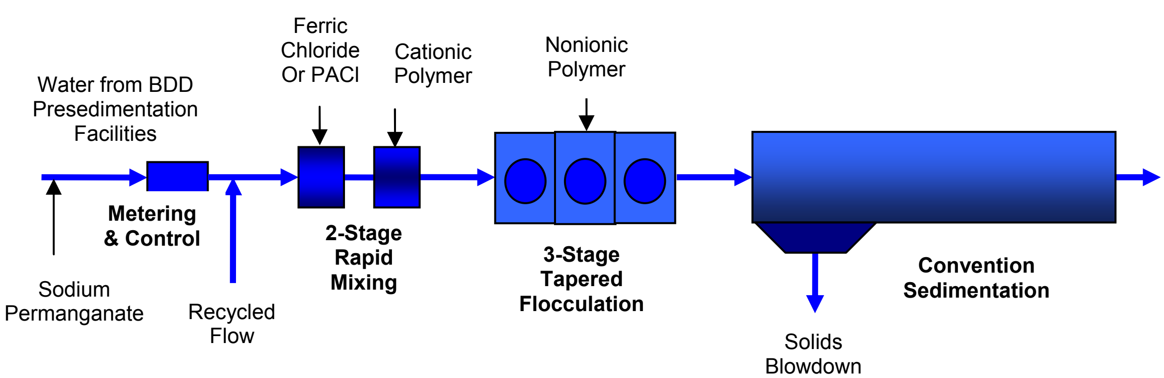


Corrosion is Detrimental to Distribution Systems

Presedimentation Evaluation - Settling of the water from the Rio Grande was evaluated during the third round of testing in order to collect design data for the sedimentation facilities proposed near the river. The turbidity in two samples dropped 32 to 56 percent in just over one hour. This substantial reduction will lessen the volume of residuals generated at the MRC WTP. The solids removed at the river will be returned to the river or trucked off site, potentially used for purposes other than disposal.

Recommended WTP Layout and Process Overview

The most appropriate treatment process was selected based on a screening of alternatives and input from City Water Division staff. A comparison of the alternatives was completed which considered advantages and disadvantages, costs, maintenance requirements, flexibility and reliability. The results of the evaluation were used to develop recommended process approaches for the treatment plant facilities which are shown in the following figures. The recommended processes are briefly discussed below.



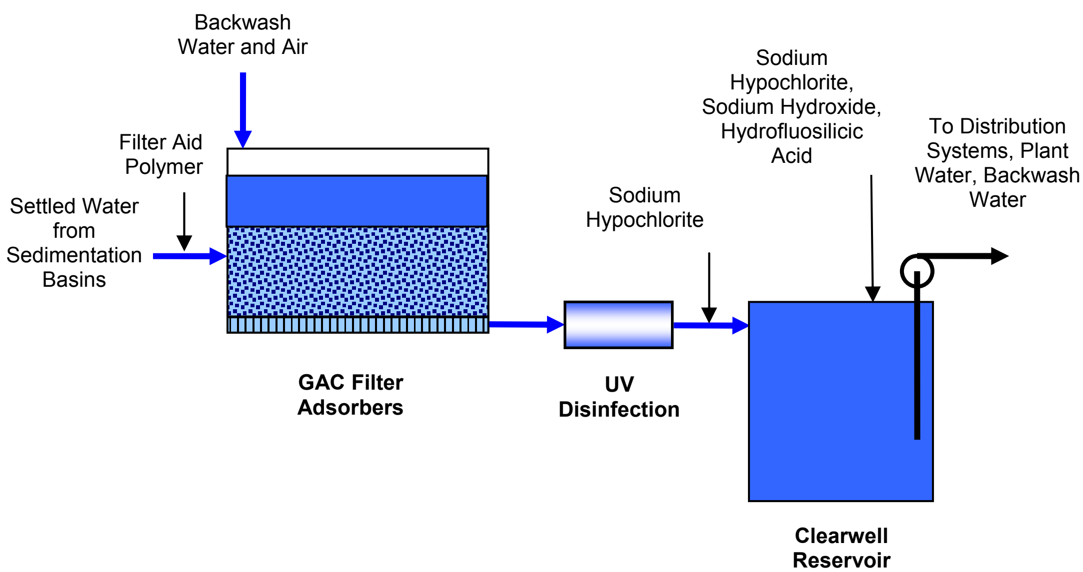
Coagulation, Flocculation and Sedimentation Processes

Preoxidation – Sodium permanganate will be used as a pre-oxidant for iron and manganese removal, taste and odor causing compound control, algae control, and enhancement of coagulation.

Coagulation – A two-stage rapid mix process will be used for injection of the primary coagulant (ferric chloride or polyaluminum chloride) and a coagulant aid polymer. The primary coagulant will be injected at the first stage of rapid mixing. The flow will then be divided into three process trains with the second stage of mixing at the head end of the flocculation basins.

Flocculation – Three treatment trains, each with three stages of flocculation to create a settable floc. Horizontal paddle wheel flocculators with variable frequency drives to provide good tapered flocculation.

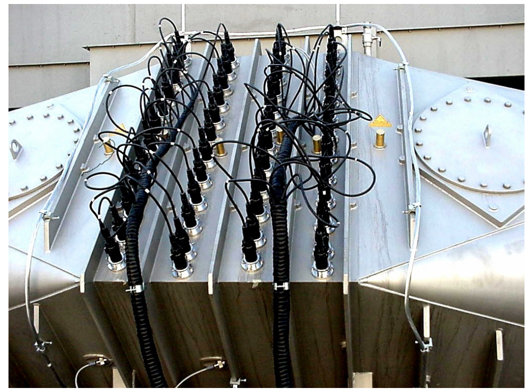
Sedimentation – Three long rectangular sedimentation basins will provide good removal of settable floc. Sludge will be pushed to sludge hoppers at the front end of the basins with either chain and flight collectors, or newer systems such as a SuperScraper. Sludge will be withdrawn from the hoppers using telescoping valves.



Filtration, UV and Storage Processes

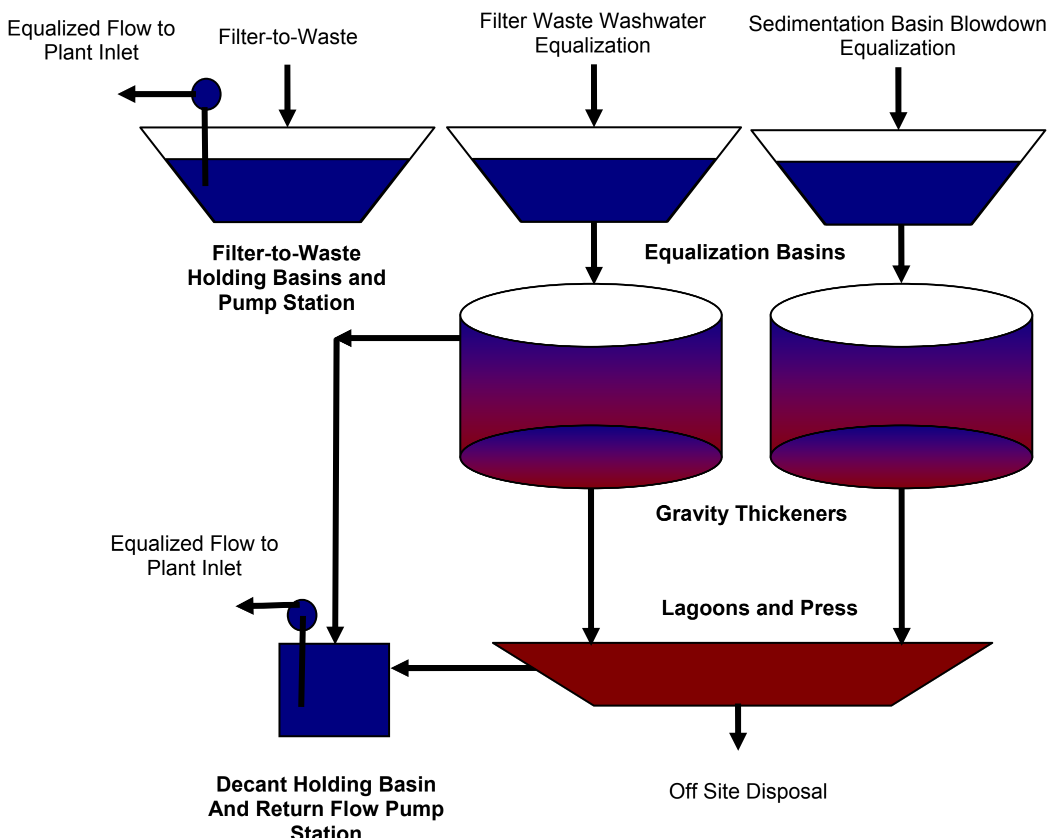
Filtration – Six GAC filter adsorbers will provide turbidity and particle removal, additional TOC removal, SOC and VOC removal, and taste and odor causing compounds removal. Four filters will provide the peak treatment flow with one additional filter in backwash mode and another filter in standby or maintenance mode. A filter aid polymer will be added to the settled water prior to the filters. Backwash water and air will be provided through an underdrain system for particle removal of the media. Filter-to-waste will be used to remove the initial, lower-quality volume of water after a filter has been backwashed and put back into service. Backwash water will be provided through pumps at the Clearwell Reservoir.

Ultraviolet Disinfection – Additional treatment goals, *Cryptosporidium* and *Giardia* inactivation will be provided by two UV reactors. A third UV reactor will be used in a standby module.



Ultraviolet Reactors for Disinfection

Clearwell Reservoir – A 15 million gallon (nominal) reservoir will be used to supply the City and County connections. An additional 0.5 million gallons will be stored in the reservoir for plant water and backwash water. Sodium hypochlorite will be introduced at the beginning of the reservoir for Virus disinfection. Sodium hypochlorite will be introduced again, after monitoring, to provide a disinfection residual in the distribution systems. Booster Stations 4A and 5A will be located at the Clearwell Reservoir for distributing flow to the City and County.



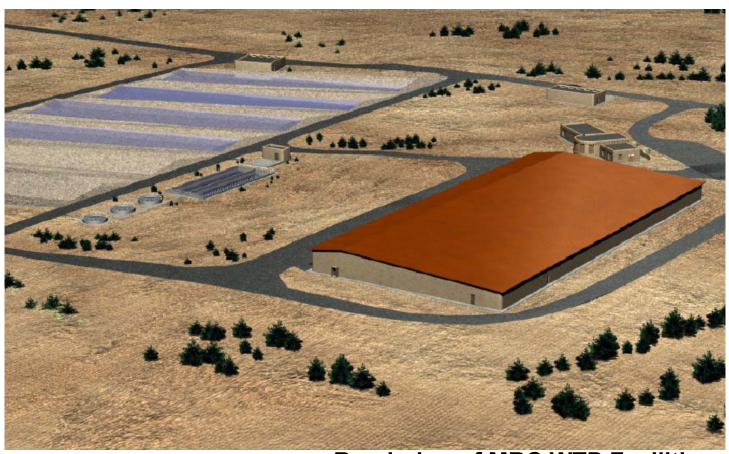
Solids Handling Processes

Solids Handling – Equalization basins, gravity thickeners and drying bed lagoons will be used to treat the solids streams from the sedimentation basins and the filters. Decant from the lagoons will be pumped back to the head of the treatment plant. A high-rate solids dewatering process, such as a belt filter press, will be provided for additional sludge handling capacity during extremely turbid water quality periods. Dried sludge from the lagoons and press will be disposed of at the Caja del Rio landfill or possibly reused if a use can be identified. Filter-to-waste will be equalized and pumped back to the head of the treatment plant.

Construction and O&M Costs for Recommended WTP Layout

Estimated construction and annual operation and maintenance (O&M) costs have been included in this Report. Estimated construction costs were estimated for: site facilities, administration building, process basin, clearwell reservoir, solids facilities, drying lagoons, chemical facilities, miscellaneous work items, and additional provisions. The estimated annual O&M costs include: personnel, chemicals, materials and supplies, electrical power, and waste solids treatment and disposal. The estimated costs are as follows:

Estimated Construction Costs	**=**	**$60.5 million dollars**
Estimated Annual O&M Cost	**=**	**$3.0 million dollars**
Cost per 1000 gallons of treated water	**=**	**$1.31**



Rendering of MRC WTP Facilities

Recommendations for Additional Work

It is recommended that additional testing and evaluations be completed as part of the preliminary design of the MRC WTP. Recommendations are summarized in Section 5 and include additional analytical tasks such as sampling for radiological contaminants from Los Alamos, continued nitrate monitoring, and additional *Cryptosporidium* testing. Recommendations for additional bench scale or pilot testing include: evaluation of blended water from the MRC WTP and Buckman Wells with water from the City wells and Canyon Road WTP; optimizing coagulation/flocculation for TOC removal; determine EBCT and change out frequency of GAC for various TOC removal efficiencies; testing of PAC on screened Rio Grande water to fully compare the use of PAC and GAC; conducting corrosion tests; optimizing the design for UV disinfection through pilot testing; and evaluating various technologies for treatment through pilot testing and manufacturer testing.

Additional evaluations recommended include evaluating the need for a surge tank at MRC WTP as part of the booster station control strategy, determining the necessary reserve volume for Clearwell, using the water quality model to determine chlorine residuals and DBPs in the enlarged distribution system to verify chlorine dose for finished water and to determine if remote chlorination stations are necessary, evaluating the need to enclose the process basins as a potential cost savings measure, and discussing the use of Phoenix's planned GAC regeneration facilities as a potential cost savings measure.

Section 1
Overview

1.1 Background

Water in Santa Fe is obtained from multiple sources, forming a supply and deliver system that has evolved over time as the City's service base grew and constraints on local sources became more evident. The City's three primary sources of supply today include: surface water from the Santa Fe River watershed; groundwater from the City Well Field along the Santa Fe River; and groundwater from the Buckman Well Field near the Rio Grande. The Santa Fe River watershed is primarily runoff from the Sangre de Cristo Mountains. This water is stored in McClure and Nichols reservoirs. Surface water in the reservoirs is treated via conventional treatment at the Canyon Road Water Treatment Plant, located below the reservoirs. Historically, surface water comprises 40 percent of the total City supply but the City relies completely on groundwater during winter months when water demand decreases until snow-pack runoff can refill the two reservoirs. Currently, the three sources of water combined barely supply enough water to meet the City's demands when conservation measures are in place. Figure 1-1 identifies the City's current water sources.

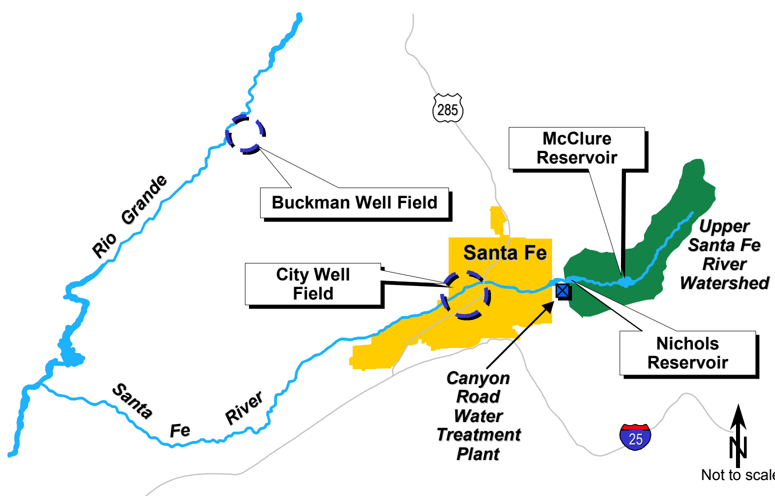


Figure 1-1. Santa Fe's Existing Sources of Water Supply

Although the City has three separate water sources, the prevalence of a drought and growth in the region has increased the City's reliance on groundwater. Increased drawdown levels and impacts on tributaries and other groundwater wells in the County are a growing concern. Several studies identifying additional water supply sources have been prepared over the past seven years. The focus of these studies has been to recommend the best means for the City and Santa Fe County to utilize their portion of San Juan-Chama (SJC) Project water. The City and County have a total SJC Project water right of 5,605 acre feet per year (AFY). SJC water is a result of a Bureau of Reclamation Project that constructed tunnels to divert water from southern Colorado into the Rio Grande basin of New Mexico. The project water is stored in reservoirs in northern New Mexico. To date, the City has only used SJC water to offset the effects on the Rio Grande from pumping the Buckman Wells. Planning, design and construction of the Buckman Direct Diversion project on the Rio Grande was ultimately recommended as a result of the studies previous conducted. The County has an identified need of 1,700 AFY, of which an additional 1,325 AFY must be identified, purchased, and possibly transferred. This project will provide a total of 6,930 AFY for the City and County.

The City of Santa Fe, Santa Fe County and Las Campanas are currently cooperating on the completion of an environmental impact statement and permitting for a water diversion facility along the Rio Grande at the north end of Buckman Road that will utilize SJC contract water. Construction of a new water treatment plant (WTP) located at the north end of the Municipal Recreation Complex (MRC) along Caja del Rio Road, south of Las Campanas, is a major component of the Buckman Direct Diversion Project. As proposed, the MRC WTP will have a peak treatment capacity of 15 million gallons of water per day (mgd) and an average flow rate of approximately 5 mgd.

Rio Grande water will be diverted through submerged, inclined screens (2-mm openings) constructed within the river and pumped via a low-head pump station to a presedimentation facility. Either high-rate settling basins or high-rate mechanical solids separation equipment will be used to remove sand and grit sized between 0.3 and 2-mm to protect pumping equipment. The water will then be pumped via two new booster pump stations (BS1A and 2A) to the MRC WTP. A portion of the diverted water (in addition to the 15 mgd) will be pumped through a third booster station (BS3A) to Las Campanas for their use. Figure 1-2 is a schematic of the Buckman system with the addition of the Buckman Direct Diversion.

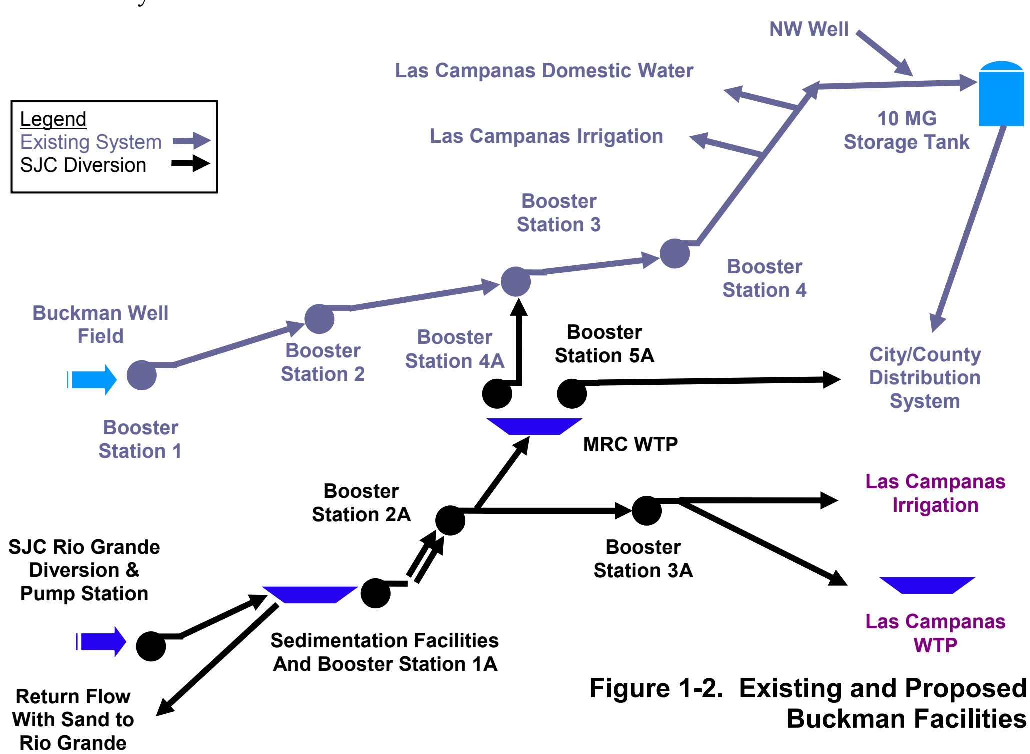


Figure 1-2. Existing and Proposed Buckman Facilities

CDM was contracted to complete a water quality study and evaluation of the Rio Grande water to provide information necessary for the further study and design of the MRC WTP. The scope of work included the following evaluations:

- Regulatory requirement review
- *Cryptosporidium* and microbial study
- Taste and odor assessment
- Contaminants study
- Organics and TOC evaluation
- Chemical dose and optimization review
- Disinfection by-product assessment
- Disinfection testing and analysis
- Corrosion and blending study
- Presedimentation evaluation

These evaluations have been documented within technical memoranda which are included in Volume 2 of this Report. A technical memorandum was not prepared for the presedimentation evaluation. The results are discussed in Section 2 of this report. The water qualify studies were limited to three sampling periods and bench-scale testing. As such, the studies do not form a complete basis of design but provide valuable information for performing preliminary and final design of the facilities. Recommendations for additional testing and/or evaluations are included in this Report. Based on the developed information, a conceptual treatment train and site layout were prepared to provide a basis for estimating construction and operation and maintenance (O&M) costs. These items provide critical information for the City's planning process and are to be refined further during preliminary design.

1.2 Objectives

The main objective of this project is to collect and evaluate data for use in preliminary and final design of the MRC WTP, which is proposed to treat water from the Rio Grande as part of the Buckman Direct Diversion Project. Another objective of this project is to provide critical planning information for the City's use in moving into the design phase.

1.3 Regulatory Summary

Drinking water quality is regulated by the United States Environmental Protection Agency (EPA) and the New Mexico Environmental Improvement Board (NM EIB) Drinking Water Standards 20 NMAC 7.1 through a number of existing regulations. New regulations were recently promulgated by the EPA and additional regulations are currently under development. The goals of these regulations are to improve water quality and minimize public health risks.

The designed and constructed plant facilities must allow Santa Fe to easily comply with all applicable regulations. Therefore, the proposed and anticipated regulations must be considered during design of the MRC WTP. The technical memorandum titled *Regulatory Requirements Review* is included in Appendix A of Volume 2 of this Report. Table 1-1 summarizes the provisions of each regulation that will affect the design of the MRC WTP based upon the discussion presented in the technical memorandum.

Table 1-1. Summary of Provisions of Regulations Affecting Design of the MRC WTP

Regulation	Provisions
Total Coliform Rule (TCR)	1. Requires monthly sampling for total coliforms at designated sampling locations in the distribution system. Samples must be absent of total coliforms in 95 percent of all samples in the month or system in violation. Positive samples must be verified by testing *E. Coli* and fecal coliform and both must be absent or system in violation. 2. The plant must be designed to fully disinfect ambient fecal matter coliforms so it does not enter the distribution system, resulting in TCR violations.
Surface Water Treatment Rule (SWTR)	1. Treatment must achieve 3.0-log (99.9%) removal/inactivation for *Giardia lamblia*. Filtration results in a 2.5-log credit requiring a 0.5-log credit from chemical disinfection. 2. Treatment must achieve a 2.0-log (99%) removal/inactivation for viruses. Filtration results in a 2.0-log credit requiring a 2.0-log credit from chemical disinfection. 3. Combined filtered water turbidity ≤ 0.5 NTU in at least 95% of monthly samples and combined filtered water turbidity never to exceed 5 NTU. 4. Turbidity monitoring continuously or by grab samples every four hours. 5. Establishes chemical disinfection credit based upon the Ct value (disinfection residual concentration "C" multiplied by the disinfection contact time "t").
Lead and Copper Rule	1. Requires periodic monitoring of designated locations in the distribution system for copper and lead concentrations. 2. Action levels for lead and copper of 0.015 mg/L and 1.3 mg/L, respectively. 3. Treatment to prevent corrosion or replacement of pipes may be necessary if action levels exceeded in more than 10 percent of the samples.
Interim Enhanced Surface Water Treatment Rule (IESWTR)	1. Added a 2.0-log removal/inactivation requirement for *Cryptosporidium*. Allowed conventional sedimentation/filtration treatment plants a 2.0-log credit if turbidity provisions are met. 2. Reduced turbidity requirements to the following: combined filtered water turbidity less than or equal to 0.3 NTU in at least 95% of monthly samples and combined filtered water turbidity never to exceed 1 NTU.

Table 1-1. Summary of Provisions of Regulations Affecting Design of the MRC WTP

Regulation	Provisions
Stage 1 Disinfectants / Disinfection By-Products Rule (DBPR)	1. Set TOC removal requirement percentages dependent upon the source water alkalinity and TOC concentration. 2. Established DBP MCLs as follows: TTHM - 80 µg/L; HAA - 60 µg/L; bromate - 10 µg/L; and chlorite - 1.0 mg/L. 3. Required monitoring in the distribution system to verify compliance with the DBP MCLs.
Radionuclides Rule	1. Established MCL for uranium of 30 µg/L and retains MCLs for gross alpha particles, beta/proton emitters, and radium 226/228 2. Initially requires four quarterly samples at entry points to distribution system to determine compliance with rule and to set continued monitoring schedule. 3. Management techniques or treatment will be necessary if uranium MCL is exceeded.
Arsenic Rule	1. Lowered the total arsenic MCL to 10 µg/L in drinking water.
Filter Backwash Recycling Rule	1. Designates that all recycle streams in the WTP are returned to the front of the plant such that the recycles water is treated through all plant processes.
Long Term 2 ESWTR (LT2ESWTR)	1. Requires systems to collect and analyze 24 monthly samples of surface water sources for *Cryptosporidium* and turbidity. 2. Monitoring results dictate if additional treatment of *Cryptosporidium* based upon the running annual average concentration from the collected samples. The average concentration indicates which "Bin" the source water is classified. 3. Requires none, 1-0, 2-0 or 3.0-log additional treatment above the 2.0-log requirements in the IESWTR. 4. Established a toolbox of processes that can be used to meet the additional removal requirements.
Stage 2 DBPR	1. During the first phase, revises compliance based upon a locational running annual average at the highest concentration areas in the distribution system. MCLs slightly higher than the Stage 1 DBPR: TTHM - 120 µg/L and HAA - 100 µg/L. 2. During the second phase, the MCLs are reduced to 80 µg/L and 60 µg/L.

1.4 Report Organization

This report is organized into two volumes. The text for the report is included as Volume 1 and divided into the following sections:

- Section 2 is a review of the testing results and treatment implications. The technical memoranda in Volume 2 are summarized and regulatory and process requirements are discussed. Treatment implications of the testing results and requirements are presented.
- Process alternatives and analyses are presented in Section 3. A comparison of each viable treatment or facility operation at the MRC WTP is presented. Conclusions and recommended treatment options are discussed. The design criteria, based upon the previous evaluations, are presented at the end of Section 3.

- A presentation of the estimated construction and operation and maintenance costs are provided in Section 4.
- Section 5 provides a summary of the recommended facilities and presents recommendations for additional work prior to, or as part of, preliminary design.

Volume 2 of this report includes the technical memoranda that present the regulatory summary and the results of the testing conducted for this project and the laboratory results. Volume 2 is divided into ten appendices (A through J).

Section 2
Testing Results Review and Treatment Implications

2.1 Overview

The Buckman Direct Diversion Project is a large scale project that will serve the City of Santa Fe, Santa Fe County, and Las Campanas. As discussed in Section 1, a draft environmental impact statement (EIS) has been prepared for the Project. Much of the Project will be constructed on lands managed by the Bureau of Land Management (BLM) and the United States Forest Service (USFS) requiring right-of-way permits for the facilities. An accurate assessment of the land requirements was necessary for the EIS and the right-of-way permitting. Therefore, an initial determination of the most appropriate, yet conservative, treatment train was prepared.

Numerous strategies can be used to meet treatment goals and regulations. This Section discusses feasibility of certain options for the MRC WTP according to:

- Cost-effectiveness - capital and operational costs and now to see what happens when it wraps
- Ease of operation and maintenance
- Ability to meet anticipated future regulations
- Flexibility in treating varying water quality

There are three basic water treatment processes that are applicable: membrane filtration, direct filtration, and conventional treatment. Water quality information on the source water (Rio Grande) was collected and evaluated in an effort to predict the raw water quality the plant will be treating throughout the year. The United States Geological Survey (USGS) operates a streamflow gaging station at the Otowi Bridge located approximately three miles upstream from the proposed diversion location. The USGS also collects water quality data at this location. Water quality data for the period of 1990 to 2002, and that collected during this project, was utilized to determine the appropriateness of treatment options. The Rio Grande's water quality was found to vary significantly throughout the year, have a high solids content and turbidity during some periods, have great temperature fluctuations, and contain some metal constituents. Alkalinity, pH and organic content also vary over the course of the year. The wide fluctuations in the raw water characteristics dictate the need for a robust and flexible water treatment plant design.

Membrane filtration would not be the most cost-effective treatment option because of the high solids content would likely require significant pre-treatment. Therefore, membrane filtration is probably the most expensive technology. Direct filtration would not be effective in handling the large variation in raw water quality, would not efficiently remove the total organic carbon (TOC), and filter run times could be too short. Conventional treatment can be designed to remove the TOC, is resilient to changing raw water conditions including fluctuating solids content, and is already used by the City of Santa Fe at the Canyon Road Water Treatment Plant. Therefore, a conventional treatment process was used as a basis to develop and evaluate alternatives for the MRC WTP.

The goals of the water quality evaluations and treatability studies are to:

- Provide critical information for further testing and design of the MRC WTP
- Provide a basis for the planning level costs
- Confirm land area for the facilities based on an acceptable method of treatment

A series of technical memoranda were prepared documenting the results of the studies and evaluations. Those technical memoranda are included in Volume 2 of this Report. The following sections present a summary of the technical memoranda data and conclusions, identify the applicable regulatory requirements, and select process alternatives based upon the data and requirements.

2.2 *Cryptosporidium* / Microbial Study Results and Implications

2.2.1 Testing Results

A *Cryptosporidium/Giardia* microbial study was conducted with the assistance of City of Santa Fe staff as part of this project. The City of Santa Fe collected water samples from the proposed diversion location for *Cryptosporidium* and *Giardia* analyses. The results of the analyses are shown in Table 2-1.

Table 2-1. Summary of *Cryptosporidium* and *Giardia* Concentrations

Sample Date	Volume Tested (Liter)	Turbidity (NTU)	*Cryptosporidium*		*Giardia*		River Daily Flow (cfs)
			# Detected [1]	# / Liter [2]	# Detected [1]	# / Liter [2]	
08/13/03	7.0	150	0	0	3	0.4	481
08/25/03 [4]	9.0	117	0	0	63	7	966
09/11/03	0.0984	2590	0	0	1	10	774
10/09/03	2.0	71.2	0	0	24	12 [3]	372
11/06/03	6.116	16.1	1	0.2	68	11 [3]	382
12/04/03	5.0	25.3	0	0	19	4	600
01/06/04	10.0	7.8	0	0	23	2	385

NTU = Nephelometric Turbidity Unit
cfs = Cubic Feet per Second
[1]Detected = Includes all oocysts and cysts of *Cryptosporidium* or *Giardia* observed, respectively, using EPA Test Method 1623.
[2]Laboratory presents *Cryptosporidium* concentration (#/L) as detection limit (see laboratory report).
[3]Laboratory results are rounded to the nearest 10 (see laboratory report).
[4]Sample was collected after a rain event on 08/25/03.

Although only seven months of data were collected and a running annual average could not be calculated, the values shown in Table 2-1 can still be utilized for a generalization of the 12-month *Cryptosporidium* average concentration. The average (or mean) *Cryptosporidium* concentration for this study is calculated as 0.03 per liter, based upon the seven discrete samples.

Additional information on the *Cryptosporidium/Giardia* microbial study can be found in the technical memorandum included in Appendix B of Volume 2.

2.2.2 Requirements

Cryptosporidium is prevalent in many source waters and its removal and/or inactivation in water treatment is essential to protect the public's health. The Interim Enhanced Surface Water Treatment Rule (IESWTR) added a 2.0-log *Cryptosporidium* removal/inactivation requirement and reduced the filtered water turbidity requirements to 0.3 NTU in 95 percent of all samples, never to exceed 1.0 NTU. The IESWTR allowed conventional treatment plants a 2.0-log *Cryptosporidium* removal/inactivation credit if the reduced turbidity provisions are met.

In the summer of 2003, the EPA proposed a new drinking water regulation with the objective of determining the level of source water *Cryptosporidium* contamination and the appropriate level of treatment. With the intent of providing more uniform public health protection, the new regulation, titled the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), is to be promulgated by early to mid-2005. Additional information regarding the IESWTR and the LT2ESWTR can be found in the CDM technical memorandum titled *MRC WTP Water Quality Studies and Evaluation Project Regulatory Requirements Review and Evaluation,* Appendix A of Volume 2.

The LT2ESWTR bases the additional treatment requirement upon a running annual average of the *Cryptosporidium* concentration in the source water. The concentration determines the Bin Classification. Table 2-2 shows the Bin Classifications and the associated additional treatment requirements.

Table 2-2. Bin Classifications by Mean *Cryptosporidium* Concentrations and Required Additional Source Water Treatment

Bin	Mean *Cryptosporidium* Concentration	Requirements
1	Less than 0.075/Liter (L)	No additional treatment required [1]
2	Greater than or Equal to 0.075/L, but Less than 1.0/L	1.0-log additional treatment [2]
3	Greater than or Equal to 1.0/L, but Less than 3.0/L	2.0-log additional treatment [3]
4	Greater than or Equal to 3.0/L	2.5-log additional treatment [3]

[1]Beyond treatment required under existing Surface Water Treatment Rule (SWTR).
[2]Public Water Supply (PWS) may use any technology or combination of technologies from the toolbox. (See Draft Rule for Toolbox explanation).
[3]Greater than or equal to 1.0-log of the required additional treatment from ozone, chlorine dioxide, UV, membranes, bag/cartridges, or bank filtration.

Based on the 7-month average concentration of 0.03 per Liter, the MRC WTP would have a Bin 1 Classification, as shown in Table 2-2. The data collected can not be used for grandfathering of the data as samples did not meet minimum sample volume analysis or pellet size requirements and the samples could not be taken after the presedimentation process planned at the river. According to EPA Region 6, the presedimentation process effluent will be the compliance location for collection of samples. Also, the additional five months of data needed for an annual average could have resulted in a higher *Cryptosporidium* concentration. Therefore, the actual running annual average may be different than that presented here.

It is therefore recommended that the MRC WTP be designed to satisfy the requirements of a Bin 2 Classification in achieving a 3.0-log (99.9 percent) removal/inactivation of *Cryptosporidium*. The filtration process of a conventional treatment plant is automatically allowed a 2.0-log credit if stringent turbidity provisions are met. Additional processes will be required to achieve the 1.0-log additional removal/inactivation credit at the MRC WTP. It is recommended that additional samples be collected prior to or during preliminary design to complete the collection of at least one year of data in order to verify the bin classification.

2.2.3 Identification of Process Alternatives

Table 2-3 presents a toolbox of options that can be used to meet the 1.0-log additional *Cryptosporidium* removal requirement.

Table 2-3. *Cryptosporidium*/Microbial Toolbox of Options

Toolbox Option	Proposed Credit	Applicable to MRC WTP Design?
Presedimentation Basin with Coagulation at WTP	0.5-log	Yes, presedimentation prior to conventional treatment train improves performance and may reduce operating costs.
Lower Finished Water Turbidity	0.5-log for combined filter effluent (CFE) <0.15 NTU in 95% of samples per month 1.0-log for individual filters <0.15 in 95% of samples per month	Yes, within capabilities of a well designed and operated conventional treatment facility.
Second Stage Filtration	0.5-log	No, requires additional capital and operating costs.
Membranes	>2.5, credit equal to demonstrated removal efficiency in challenge test	Possible, used in lieu of filtration requiring a 2-log minimum *Cryptosporidium* removal performance of the membranes, easily met by low pressure membranes. Requires clarification prior to the membranes for removal of solids. Newer technology low pressure membrane is more suitable for the water quality than reverse osmosis or nano-filtration.
Chlorine Dioxide	Credit based on CT table	Possible, newer technology uses other chlorine sources (hypochlorite) rather than the traditionally used chlorine gas source to generate the chlorine dioxide. May have additional benefits including taste and odor (T&O) reduction, DBP reduction, and/or improved filtration.

Table 2-3. *Cryptosporidium*/Microbial Toolbox of Options

Toolbox Option	Proposed Credit	Applicable to MRC WTP Design?
Ozone	Credit based on CT table	Yes, requires on-site ozone gas generation, injection, and detention structures. Usually utilizes liquid oxygen for ozone generation. May have additional benefits including T&O reduction, DBP reduction, TOC removal, and/or improved filtration.
UV	Credit based on demonstration of compliance with UV dose table	Yes, requires additional valves and piping for UV units. Allows reduced DBP formation as an additional benefit.
Demonstration of Performance	1.0-log credit based on average spore removal 4.0-log based on 1 year of weekly monitoring	No, however, should not assume additional credit beyond typical values for processes. Design should incorporate a non-operational method of meeting treatment goal.

The use of a presedimentation process with coagulation at the plant may be advantageous as discussed in Table 2-3. A separate presedimentation process will be employed near the river but it will not include the use of coagulant chemicals for numerous reasons. The use of a presedimentation basin at the plant will be evaluated further. Second stage filtration would require an additional process be implemented and will not be evaluated further. The use of membranes would still require pretreatment consisting of clarification. Not enough information is currently known to determine if other factors, such as organic fouling, could prove problematic with the operation of membranes with this water source. Promising newer technology, including low pressure submerged membranes should be investigated further possibly by sending raw water samples to various equipment manufacturers for testing and recommendations. Because of the limited data, membranes for *Cryptosporidium* removal will not be considered further in this report.

Chlorine dioxide has numerous advantages including taste and odor (T&O) control and iron and manganese removal. It also has been used at other plants, such as the El Paso Water Utilities Canal WTP in combination with chlorine based disinfectants to synergistically reduce DBP formation. However, chlorine dioxide requires a higher dose and/or contact time for a 1.0-log *Cryptosporidium* inactivation than other options and will not be considered further for *Cryptosporidium* inactivation.

The additional 1.0-log credit could be obtained through lower finished water turbidity. However, this relies more on operation of the facilities rather than the design of the facilities. As a more conservative approach, the addition of either ozone or UV disinfection provides the additional credit, is a multi-barrier approach to treatment and disinfection, and helps minimize disinfection by-product formation. Therefore, the use of ozone and UV will be compared in Section 3.

2.3 Taste and Odor Evaluation Results and Implications

2.3.1 Testing Results

A taste and odor (T&O) evaluation was conducted as a part of this study. Three rounds of sampling of the raw Rio Grande water were analyzed in the laboratory. Data collected during the three rounds of testing were within historical water quality ranges for the Rio Grande near the proposed diversion location. The results of the testing indicate that odor constituents were not present during the three rounds of testing and may only be an occasional concern. Taste constituents were present in all three rounds of testing, and iron and manganese were the most likely constituents to be present at levels that could cause taste complaints if concentrations are not reduced through treatment. Other constituents such as alkalinity, sodium, hardness, and total dissolved solids (TDS) were found to be higher than optimal but at significantly lower levels than the Buckman Wells and thus probably imperceptible to customers. Natural occurring organic matter (NOM) and synthetic organic contaminants (SOCs), such as herbicides and pesticides, may potentially contribute to taste complaints. Algal bio-products were not present but algae could be problematic if presedimentation ponds are used near the river and if exposed open basins are used at the plant. Refer to the *Taste and Odor Evaluation Technical Memorandum* included in Appendix C of Volume 2 for additional information on the study.

2.3.2 Requirements

Most of the constituents that contribute to T&O concerns in water are either not regulated or are only regulated through secondary (unenforceable) standards. There are secondary standards for iron, manganese, threshold odor number, sodium, and TDS. Harness is not regulated. The amount of NOM in the water is regulated under the Stage 1 DBPR. The Stage 1 DBRP, summarized in Table 1-1, established minimum TOC removal requirements based upon the source water TOC and alkalinity concentrations. Removal of TOC to meet the Stage 1 DBPR requirements will also reduce T&O concerns from NOM.

Although not based upon a regulation, customers' acceptance of the treated water is the main purpose in reducing T&O issues and therefore meeting the secondary standards will be a goal of the treatment processes.

2.3.3 Identification of Process Alternatives

Because of potential T&O issues identified above, implementation of options to control T&O problems is recommended. Table 2-4 presents a toolbox of options for use in selection appropriate process alternatives.

Table 2-4. Taste and Odor Toolbox of Options

Issue	Toolbox Options	Applicable to MRC WTP Design?
Iron and Manganese[1]	Potassium or sodium permanganate	Yes, permanganate oxidizes iron and manganese effectively. Precipitate is readily filtered from treated water with conventional filters. Permanganate has other benefits such as algae control and aiding in coagulation.
	Chlorine dioxide	Possible, newer technology uses other chlorine sources (hypochlorite) rather than the traditionally used chlorine gas source to generate the chlorine dioxide. May have additional benefits including color removal, *Cryptosporidium* inactivation, DBP reduction, and/or improved filtration.
	Ozone	Yes, requires on-site ozone gas generation typically using liquid oxygen, injection, contactor basins, and off-gas destruction. May have additional benefits including color removal, *Cryptosporidium* inactivation, DBP reduction, and/or improved filtration.
	Greensand filtration	No, costly option for periodic event.
Algae or Algae Bio-products	Sodium hypochloride	Yes, bulk delivery or on-site generation, also, can use MIOX equipment as used at other City facilities.
	Chlorine dioxide	Possible, newer technology uses other chlorine sources (hypochlorite) rather than the traditionally used chlorine gas source to generate the chlorine dioxide. May have additional benefits including color removal, *Cryptosporidium* inactivation, DBP reduction, and/or improved filtration.
	Ozone	Yes, requires on-site ozone gas generation typically using liquid oxygen, injection, contactor basins and off-gas destruction. May have additional benefits: color removal, DBP reduction, and/or improved filtration.
	Dissolved Air Flotation	Yes, replaces sedimentation process and uses air bubbles to float light floc which is skimmed off the surface. Less effective in highly turbid waters.
	Copper Sulfate	Yes, use of copper sulfate when algae blooms occur will minimize the production of bio-products and reduce the algae impact on filtration. Would require use of lagoons for presedimentation near the river.
	Potassium or sodium permanganate	Yes, typically controls algae buildup in basins. May need to be used in conjunction with copper sulfate upstream of the plant during extreme algae blooms.
NOM	Enhanced coagulation / sedimentation / filtration	Yes, standard conventional treatment processes with enhanced coagulation can remove organic carbon, the biggest component of NOM in the source water.
	Powdered Activated Carbon (PAC)	Yes, requires sufficiently high dose and contact time for organics removal. MIB and geosmin require even longer contact time.
	Granular Activated Carbon (GAC) filter adsorption	Yes, provides good removal of humic fraction of NOM. Specific Ultraviolet Absorbance (SUVA) range indicates majority of NOM is humic.
	Potassium or sodium permanganate	Yes, has been used for mild T&O control.
	Dissolved Air Flotation	Yes, replaces sedimentation process and uses air bubbles to float light floc which is skimmed off the surface. Less effective in highly turbid wastes (NTU >50)
	Biologically Active Filters (BAF)	Yes, requires oxidation of organics to biodegradable compounds, as with ozone. More effective with GAC.
	GAC Contactors	Yes, provides good removal of humic fraction of NOM. SUVA range indicates majority of NOM is humic.

[1] Sodium, hardness, alkalinity, TDS levels are moderate, however levels are less than in Buckman Wells and should not cause taste problems.

Chlorine dioxide is identified in Table 2-4 as an option for removing iron and manganese and algae and algae bio-products. Typically, chlorine dioxide is generated on-site from chlorine gas, which presents significant safety concerns. OSHA Process Safety Management and EPA Risk Management Program regulations require extensive safety planning if the stored chlorine gas volume exceeds the regulated threshold volumes. Because of the increased regulatory requirements and the inherent dangers with chlorine gas, the Canyon Road WTP converted the chlorine gas facilities to MIOX (sodium hypochlorite) facilities many years ago. The use of chlorine gas (either for chlorine disinfection or for the generation of chlorine dioxide) will not be further evaluated for use at the MRC WTP. More recently, newer technologies use other chlorine -based disinfectants (hypochlorite) to generate the chlorine dioxide. However, testing of the chlorine dioxide to determine DBP formation, demand, and other design considerations must be conducted prior to further consideration. With the limited date on the suitability of chlorine dioxide, it will not be carried forward in this evaluation. However, the numerous benefits of chlorine dioxide merit additional consideration.

Greensand filtration is another option in Table 2-4 that is deemed inappropriate for the MRC WTP. Greensand filtration is costly and there are limited additional benefits to greensand filtration. The removal of iron and manganese can be accomplished with the use of permanganate or ozone, both of which have significant benefits beyond iron and manganese removal.

All other options listed in Table 2-4 will be carried forward and evaluated in Section 3 of this report.

2.4 Contaminants Study Results and Implications

2.4.1 Testing Results

Sampling and laboratory analysis were conducted to determine the levels of synthetic organic contaminants, nitrates, selected metals, arsenic and radionuclides that may be present in the Rio Grande water during three testing periods. Additionally, four Buckman groundwater wells and Booster Station 3 were tested for these contaminants during one period. Details of this study can be found in the *Contaminants Study Technical Memorandum* included in Appendix D of Volume 2. A review of the source water quality for specific contaminants regulated with drinking water standards is important because high levels of regulated contaminants may require the construction of specific unit processes capable of removing the contaminant.

The analyses and historic data (from Otowi Gaging Station) indicate that only a few constituents are present above drinking water standards in the raw water at Buckman. These constituents include turbidity, color, aluminum, iron, manganese, and nitrate.

Samples from several Buckman Wells were also collected during this project. Collection of water quality data was necessary for use in blending and corrosion analysis (discussed later in this report) and to acquire data from newly constructed wells. Existing data and newly collected data for the Buckman wells indicate that two contaminants are present that may pose regulatory compliance concerns: arsenic and uranium. Because certain wells already posed water quality concerns, investigation of compliance solutions is necessary. One potential solution could be treatment at the MRC WTP. Water samples were collected from nine of the thirteen wells and of those wells, five exceed the arsenic Maximum Contaminant Level (MCL) of 10 µg/L. Since Buckman Wells 10, 11, 12, and 13 were recently put into operation, additional testing of these wells is recommended. Well 2 was the only well of the nine where uranium approaches or exceeds the proposed MCL.

2.4.2 Requirements

The National Primary Drinking Water Standards (primary standards) protect the public's drinking water supply by limiting the concentration of specific contaminants that can affect public health. These standards are based upon the various regulations such as the Arsenic Rule and the Radionuclides Rule. There currently are primary standards for over 90 contaminants and the standards are in the form of a MCL. The primary standards include microbes, radionuclides, inorganics, volatile organics, synthetic organics, disinfectants, disinfection by-products and methyl t-butyl ether (MTBE). The National Secondary Drinking Water Standards (Secondary Standards) are unenforceable guidelines regarding the maximum concentration of contaminants that have cosmetic or aesthetic effects, not health implications.

The USGS has sampled the Rio Grande at Otowi for many years and a large amount of water quality data, for many contaminants, is available. Additionally, many constituents were tested under this project. Most constituents were either not-detected or were detected at levels significantly below drinking water standards. Refer to the *Contaminants Study Technical Memorandum* included in Appendix D of Volume 2 for additional information on the other constituents analyzed during this project. Of the numerous constituents test, only turbidity, color, aluminum, iron, manganese, and nitrate were detected at or near their respective MCL during one or more of the three testing rounds. Treatment and/or removal of these constituents to less than 80 percent of the MCL needs to be the goal of the new MRC WTP. Table 2-5 presents the maximum concentration in the raw water by constituent, the respective MCL and the recommended treatment goal. Other than turbidity, the recommended treatment goal is 80 percent of the MCL. The turbidity treatment goal is based upon operating experience. A relatively high nitrate level (9.4 mg/L) was detected during the summer monsoon sampling period. During the other two periods, the nitrate level was non-detect (<0.1 mg/L). The high concentration could be agricultural-runoff related, an upstream wastewater treatment plant effluent discharge permit exceedance, a sampling anomaly, or a testing error. Although the detected nitrate concentration is slightly below the MCL, further testing or investigation should be conducted.

Table 2-5. Raw Water Concentrations and Treatment Goal for Identified Contaminants

Contaminant	Raw Water Concentration [2]	MCL	Treatment Goal
Turbidity	59 NTU	0.3 NTU	0.1 NTU
Color [1]	20 pt Co units	15 pt Co units	12 pt Co units
Aluminum [1]	2,500 µg/L	50-200 µg/L	40 µg/L
Iron [1]	2.2 mg/L	0.3 mg/L	0.2 mg/L
Manganese [1]	57 µg/L	50 µg/L	40 µg/L
Nitrate	9.4 mg/L	10 mg/L	8 mg/L

[1]Secondary Standard Only
[2]Measured in samples collected on August 8, 2003

Treatment of wells with the high arsenic and uranium at the MRC WTP may be one option to address compliance with the new Arsenic and Radionuclides Rules. The design of the MRC WTP must incorporate appropriate technologies to handle these contaminants if deemed an appropriate compliance solution. Table 2-6 identifies the concentration of the contaminants in the Buckman Wells.

Table 2-6. Measured Concentrations and Treatment Goals for Contaminants Above MCLs Identified in Buckman Wells

Contaminant	Buckman Well / Concentration	MCL	Treatment Goal
Arsenic	Well 2 / 12 µg/L[1] and 9.5 µg/L[8] Well 9 / 16 µg/L[2] Well 11 / 11 µg/L[3] and 12 µg/L[7] Well 12 / 18 µg/L[4] and 11.1 µg/L[5] Well 13 / 16 µg/L[6] and 13.8 µg/L[7]	10 µg/L	8 µg/L
Uranium	Well 2 / 27.9 µg/L[1] Well 11 / <100 µg/L[3] Well 12 / <100 µg/L[4]	30 µg/L	24 µg/L
Gross Alpha	Well 2 / 15.3 pCi/L[1]	15 pCi/L	12 pCi/L

[1]Measured in samples collected on October 28, 2003
[2]Measured in samples collected on July 19, 2003
[3]Measured in samples collected on July 6, 2003, uranium detection limits too high to determine compliance
[4]Measured in samples collected on September 14, 2003, uranium detection limits too high to determine compliance
[5]Measured in samples collected by NMED on February 23, 2004
[6]Measured in samples collected on October 28, 2003
[7]Measured in samples collected by NMED on January 26, 2004
[8]Measured in samples collected by NMED on March 26, 2004

High arsenic levels may be blended down to meet the MCL. However the City will need to sacrifice production from the Buckman wells. Conveyance of well water to the treatment plant should be evaluated further since arsenic could be reduced to the treatment goal using ferric chloride or other methods. The City is currently looking into management, well rehabilitation and treatment methods for Well 2 to address the high uranium and gross alpha levels. The high uranium concentrations in Wells 11 and 12 that are shown in Table 2-6 are actually non-detect values due to using a rapid testing method with a high detection limit during well installation. Wells 10 and 13 were tested with a different analysis method and showed uranium levels of 8 μg/L, well below the MCL. Additional testing of the wells in 2004 showed a slight reduction in the arsenic concentrations but wells 12 and 13 still exceed the MCL. UPDATE WITH NEW DATA - specifically uranium data when received.

The Concerned Citizens for Nuclear Safety (CCNS) issued a report titled *New Mexico's Right to Know: the Potential for Groundwater Contaminants from LANL to Reach the Rio Grande,* August 2004. The report discusses the potential for contaminants detected in the groundwater near LANL to migrate into the Rio Grande. CCNS concluded that several radionuclides can reach the Rio Grande from springs near or upstream of the diversion location including tritium, perchlorate, americium-241, cesium-137, plutonium-238 and strontium-90. It was not part of this project's scope of work to evaluate the information in the CCNS report and these constituents were not sampled at the diversion location as part of this project. However, Santa Fe staff and community leaders wish to be proactive in assessing the potential risk to drinking water sources in order to protect customers. Therefore, CDM recommends that a review of the CCNS data be conducted and compared with other water quality data, regulatory limits, and existing groundwater modeling information. If warranted, additional groundwater and surface water sampling can be conducted to verify data presented in the report. Further work could include completion of a additional groundwater monitoring, risk assessment and determination of treatment requirements for suspected contaminants if the potential contaminant concentrations are more than trace levels compared to the regulated MCLs.

2.4.3 Identification of Process Alternatives

Numerous contaminants near or above applicable MCLs were identified during the study. Table 2-7 presents a list of options applicable to each of the identified contaminants. The table can be used to select appropriate process alternatives.

Table 2-7. Contaminants Toolbox of Options

Issue	Toolbox Options	Applicability
Rio Grande Surface Water:		**Applicable to MRC WTP Design?**
Aluminum	Enhanced coagulation / sedimentation / filtration	Yes, standard conventional treatment processes with enhanced coagulation remove aluminum at study levels.
	Reverse osmosis (RO) membrane	No, high energy process mostly used for removal of high salt, hardness, or TDS waters.
Color	Enhanced coagulation / sedimentation / filtration	Yes, standard conventional treatment processes with enhanced coagulation removes color.
	Potassium or sodium permanganate	Yes, permanganate removes color effectively but if overdosed, can carry through the plant. If conditions in the distribution system dictate, the dissolved manganese can precipitate resulting in more color problems.
	Sodium hypochlorite	No, weak oxidizing agent, and causes DBP formation.

Table 2-7. Contaminants Toolbox of Options

Issue	Toolbox Options	Applicability
	Chlorine dioxide	Possible, newer technology uses other chlorine sources (hypochlorite) rather than the traditionally used chlorine gas source to generate the chlorine dioxide. May have additional benefits including T&O reduction, *Cryptosporidium* inactivation, DBP reduction, and/or improved filtration.
	Ozone	Yes, standard equipment requires on-site ozone gas generation, typically with liquid oxygen, injection, contactor basins and off-gas destruction. May have additional benefits: T&O reduction, DBP reduction, and/or improved filtration.
Iron and Manganese	Potassium or sodium permanganate	Yes, permanganate oxidizes iron and manganese effectively. Precipitate is readily filtered from treated water with conventional filters.
	Chlorine dioxide	Possible, newer technology uses other chlorine sources (hypochlorite) rather than the traditionally used chlorine gas source to generate the chlorine dioxide. May have additional benefits including T&O reduction, *Cryptosporidium* inactivation, DBP reduction, and/or improved filtration.
	Ozone	Yes, requires on-site ozone gas generation, typically using liquid oxygen, injection, contactor basins, and off-gas destruction. May have additional benefits: T&O reduction, DBP reduction, and/or improved filtration.
	Greensand filtration	No, requires additional basins for particle filtration.
Nitrate	Enhanced coagulation / sedimentation / filtration	Yes, standard conventional treatment processes with enhanced coagulation.
	RO membrane	No, high energy process mostly used for removal of high salt, hardness, or TDS waters. Significant upstream pretreatment and produces significant waste stream.
	Ion exchange	No, requires pressure vessel or basin for well water/media contact prior to discharge. Produces a waste stream or requires media replacement when exhausted.
Turbidity	Coagulation / sedimentation/ filtration	Yes, standard convention treatment processes can remove turbidity to within treatment goals
	Enhanced coagulation / sedimentation / filtration	Yes, standard conventional treatment processes with enhanced coagulation will remove turbidity to treatment goal.
	Presedimentation basin	Yes, presedimentation prior to conventional treatment train improves performance and reduces operating costs. Still need down stream treatment to meet treatment goal.
	Micro - or ultrafiltration membranes	Possible, membrane filters can be use in addition to or in place of mixed media filters. Requires upstream clarification to operate membranes cost-effectively. Removes solids and most organic material and provides higher *Cryptosporidium* credit.

Table 2-7. Contaminants Toolbox of Options

Issue	Toolbox Options	Applicability
Buckman Wells		**Applicable to Buckman Wells?**
Arsenic	Enhanced coagulation / sedimentation / filtration	Yes, standard conventional treatment processes with ferric chloride enhanced coagulation removes many types of contaminants. Better performance with use of pre-oxidant.
	Anion exchange	No, requires pressure vessel or basin for well water/media contact prior to discharge. Produces a waste stream or requires media replacement when exhausted.
	RO membrane	No, high energy process mostly used for removal of high salt, hardness, or TDS waters. Requires upfront pretreatment processes and produces significant waste volumes.
	Lime softening	No, higher maintenance requirements and larger basin size than other technologies. Requires lime slurry feed, slurry/water separation, and slurry drying and disposal.
	Activated Alumina	No, adsorption process within vessel. Alumina replaced as exhausted.
	Granular ferric hydroxide coated filter media	No, additional filtration facilities required for particle removal. Periodic regeneration/replacement of media necessary.
	Management	Yes, blend of high arsenic water with low arsenic water will meet regulations.
Uranium	Enhanced coagulation / sedimentation / filtration	Yes, standard conventional treatment processes with alum enhanced coagulation removes many types of contaminants.
	RO membrane	No, high energy process mostly used for removal of high salt, hardness, or TDS waters. Requires upfront pretreatment processes and produces significant waste volumes.
	Ion exchange	No, requires pressure vessel or basin for well water/media contact prior to discharge. Produces a waste stream or requires media replacement when exhausted.
	Lime softening	No, higher maintenance requirements and larger basin size than other technologies. Requires lime slurry feed, slurry/water separation, and slurry drying and disposal.
	Management	Yes, blend of high uranium water with higher quality water will meet regulations.

As discussed in Section 2.3, the use of greensand filtration and chlorine dioxide were eliminated from further evaluation for use as iron and manganese reduction. Greensand filtration was eliminated in favor of options with multiple benefits and chlorine dioxide was eliminated for lack of data necessary for determining suitability. Chlorine dioxide should be evaluated during future testing activities. Membrane processes (reverse osmosis and micro- or ultra-membranes) require substantial pre-treatment, are technologies the City’s staff has little experience operating or maintaining, and are more expensive at the flow range considered. However, the newer low pressure membranes should be tested and evaluated once additional data is collected. Sodium hypochlorite was eliminated as a pre-oxidant for contaminant removal since it is a fairly weak oxidizer and causes DBP formation.

Ion exchange is effective for removing many contaminants. The existence of wastewater treatment plants upstream of the diversion location (City of Espanola and Los Alamos County) is a concern and potential source of nitrates, as is agricultural runoff. However, the historical data from Otowi indicates this has not been a pervasive issue in the past and the one high measurement recorded during the August sampling was just under the MCL. The data is not sufficient cause for the construction of a separate process unit for treating contaminants when other processes, such as enhanced coagulation are appropriate technologies that serve multiple purposes. Therefore, ion exchange will not be evaluated further. It is recommended that monitoring of nitrate in the river continue during the initial tasks for the MRC WTP.

The other technologies in Table 2-7 that were not eliminated (coagulation, enhanced coagulation, permanganate, ozone, presedimentation, and management) will be evaluated further in the next section.

2.5 Organics and TOC Evaluation Results and Implications

2.5.1 Testing Results

Testing of the Rio Grande raw water was conducted over the three study periods. TOC in the raw water was found to range between 2.4 and 5.6 mg/L. The major portion of the TOC is dissolved (DOC) and was measured between 2.1 and 3.8 mg/L. During these periods, the alkalinity ranged from 69 to 130 mg/L. Additionally, a statistical analysis was conducted on the recent data (1990 to 2002) available from the Otowi gaging station. The TOC and alkalinity vary by month in the ranges of 1.1 to 9.6 mg/L for TOC and 62 to 139 mg/L for alkalinity.

Jar testing was conducted to determine optimized chemical doses. The chemical doses were optimized for turbidity removal and not TOC removal. However, TOC removal was determined on the tests optimized for turbidity removal during the second and third rounds of testing. The measured TOC removal was close to or exceeded the TOC removal requirement in both cases. Additional information can be found in the *Organics and TOC Evaluation Technical Memorandum* included in Appendix E of Volume 2.

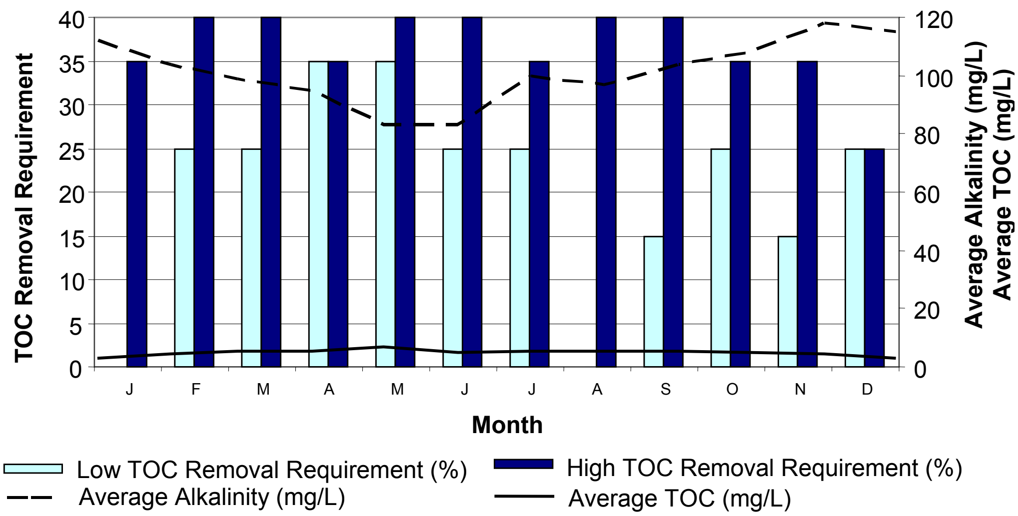
2.5.2 Requirements

The Stage 1 DBPR lowered the threshold for TOC, established MCLGs and MCLs for DBPs, and set maximum residual disinfectant levels (MRDLs) for disinfectants. In an effort to control DBPs, water agencies may need to take additional steps to further reduce the amount of TOC through the use of enhanced coagulation or other means. The regulation sets a minimum percent of TOC removal based upon the source water TOC content and alkalinity. Systems using conventional treatment or enhanced coagulation must meet TOC removal requirements unless they meet any of the exception criteria such as source water TOC with an annual average TOC concentration of less than 2.0 mg/L. While plants using technologies other than enhanced coagulation or softening do not have to meet the specified TOC removal requirements, not removing a substantial portion of the TOC will make compliance with DBP related regulations extremely difficult, if not impossible. Additional information on the Stage 1 DBPR is included in the *Regulatory Requirements Review Technical Memorandum*. Table 2-8 presents the required removal percentage of TOC based on the source water TOC and alkalinity.

Table 2-8. TOC Removal Requirements Under the Stage 1 DPBR

Source Water TOC	Source Water Alkalinity (as mg/L $CaCO_3$)		
	0 - 60 mg/L	>60 - 120 mg/L	>120 mg/L
>2.0 - 4.0 mg/L	35 %	25 %	15 %
>4.0 - 8.0 mg/L	45 %	35 %	25 %
>8.0 mg/L	50 %	40 %	30 %

Based upon the sampling data and the existing USGS Otowi water quality data, the TOC removal requirements will change on a monthly basis and could be as low as zero percent and as high as 40 percent as shown in Figure 2-1. Based upon the historical averages (1990 to 2002), the removal requirements will likely average 25 percent in the winter months (December and January) and 35 percent for the rest of the year.



Note: no visible bar indicates 0% removal requirement

Figure 2-1. TOC Removal Required Based on USGS Otowi Water Quality Data

However, based on high monthly TOC removal requirements from Otowi data, the running annual average removal requirement could be as high as 37 percent but will average 33 percent. Therefore, a treatment goal should be conservatively set by dividing the average TOC percentage (33 percent) by 0.80, resulting in a goal of 42 percent TOC removal. A treatment goal of 42 percent TOC removal also provides sufficient facilities to meet the monthly high removal requirement of 40 percent. Because compliance with TOC removal requirements is calculated on a running annual average, compliance may be easier if the removal requirements are exceeded during certain months. Therefore, a set TOC concentration goal may be advantageous. A goal of 2.0 mg/L has been suggested in other reports.

Bench scale testing outlined in Appendix E discusses that although testing was optimized for turbidity removal and not TOC removal, TOC removal requirements were nearly met or exceeded during the second and third rounds. TOC removal was not determined during the first round. Additional testing completed by EE&T discussed in their report titled *Buckman Direct Diversion (BDD) Water Treatment and Blending Analysis* showed that TOC removal with either ferric chloride or alum was increased through pH reduction (enhanced coagulation) and up to 44 percent removal was obtainable. Unfortunately, TOC removal optimization was conducted on only one sample with a low raw water TOC of 2.1 mg/L. Based upon the alkalinity measured in that sample, the regulated removal requirement was 25 percent. The ability to meet the TOC removal requirements during high TOC periods has yet to be tested. Additional bench-scale or pilot scale testing to determine optimal TOC removal conditions (chemical doses and pH) is recommended.

2.5.3 Identification of Process Alternatives

The raw water quality indicates that significant TOC removal will be required throughout the entire year. Therefore, the selected processes at the MRC WTP must be robust and flexible to manage the changing raw water quality and treatment water quality requirements in a cost-effective manner. Table 2-9 presents a list of treatment options that can be selected to achieve the TOC removal requirements.

Table 2-9. Organics and TOC Toolbox of Options

TOC Removal Requirement	Treatment Options	Applicable to MRC WTP Design?
15% - 25%	Enhanced coagulation / sedimentation / filtration	Yes, standard conventional treatment processes with enhanced coagulation removes organics as well as contaminants and turbidity.
25% - 35%	Enhanced coagulation / sedimentation / filtration	Yes, standard conventional treatment processes with enhanced coagulation removes organics as well as contaminants.
35% - 40%	Enhanced coagulation / sedimentation / filtration	Yes, standard conventional treatment processes with enhanced coagulation removes organics as well as contaminants and turbidity, additional treatment may be needed to meet 35 to 40% TOC removal.
	Biologically Active Filters (BAF) with Anthracite	Yes, biological growth on media surface can consume organic material. Requires enhanced coagulation and sedimentation to meet removal goal.
	Dissolved Air Flotation	Yes, replaces sedimentation process and uses air bubbles to float light floc which is skimmed off the surface. Additional benefits include removal of *Cryptosporidium* and *Giardia* oocysts. Does not perform well with enhanced coagulation.
	Micro- or ultrafiltration membranes	Possible, effectively removes solids and most organic material but the efficiency of DOC removal is highly dependent upon the molecular weight of the species. Probably requires upfront coagulation and other pretreatment processes. Nano-filtration used consistently for color removal but high variation of the raw water quality make the long-term, seasonal effectiveness and suitability of this technology questionable without additional testing.

Table 2-9. Organics and TOC Toolbox of Options

TOC Removal Requirement	Treatment Options	Applicable to MRC WTP Design?
	Powdered Activated Carbon	Yes, provides good organics removal and can be used intermittently when needed.
>40%	Enhanced coagulation / sedimentation / filtration	Yes, standard conventional treatment processes with enhanced coagulation removes organics as well as contaminants and turbidity, additional treatment needed to meet 40% TOC removal.
	Biologically Active Filters (BAF) with GAC	Yes, granular activated carbon (GAC) used in place of standard anthracite in filter beds provides increased adsorption of organic material on filter media and promotes biological growth on media surface that can consume organic material. Requires enhanced coagulation and regeneration or replacement of media when exhausted (every 6 months to 2 years dependent on water conditions).
	Magnetic Ion Exchange (MIEX)	Yes, MIEX used as a pretreatment process will remove dissolved organic carbon. Requires additional tanks and a waste stream is produced. Proprietary equipment with limited experience.
	Dissolved Air Flotation	Yes, replaces sedimentation process and uses air bubbles to float light floc which is skimmed off the surface. Additional benefits may include removal of *Cryptosporidium* and *Giardia* oocysts. Does not perform well with enhanced coagulation.
	Micro- or ultrafiltration membranes	Possible, effectively removes solids and most organic material but the efficiency of DOC removal is highly dependent upon the molecular weight of the species. Probably requires upfront coagulation and other pretreatment processes. Nano-filtration used consistently for color removal but high variation of the raw water quality make the long-term, seasonal effectiveness and suitability of this technology questionable without additional testing.
	GAC Contactors	Yes, deep bed GAC contactors with an Empty Bed Contact Time (EBCT) of approximately 15 minutes, depending on upstream treatment.
	Powdered Activated Carbon	Yes, provides good organics removal and can be used intermittently when needed.

All of the technologies identified in Table 2-9 were identified as applicable to the MRC WTP design. The suitability and effectiveness of the membrane processes is not known based upon the available data however. Other processes will be more dependable and possibly more cost-effective. Because of the unknowns, the membranes will not be evaluated further for TOC removal. It is recommended that additional bench-scale and pilot-scale studies evaluate the suitability of membranes for TOC removal. All other options in Table 2-9 will be evaluated in Section 3 of the report.

2.6 Chemical Dose Optimization and Evaluation Results and Implications

2.6.1 Testing Results

Bench-scale testing was performed on water collected from the Rio Grande during the three testing rounds. Testing was used to evaluate the effectiveness of three coagulants, the necessity or usefulness of coagulant aid and flocculent aid polymers, and the ability of various pre-oxidants to improve settled water quality. Testing also evaluated mixing energy, polymer feed timing and order, and pH adjustment effects.

The following chemical dosing and design optimization conclusions were made as presented in the *Chemical Dose and Optimization Evaluation Technical Memorandum* included in Appendix F of Volume 2.

- All three primary coagulants (Alum, ferric and PACl) performed well during all or some of the testing rounds, though doses of chemicals changed dramatically between the three sampling periods.
- Addition of coagulant aid and flocculant aid polymers improved the settled water quality.
- Dosing the coagulant aid polymer after the primary coagulant is more effective. Delaying the addition of the flocculant aid polymer one to two minutes after coagulation improved floc size and settling rate.
- The use of a pre-oxidant was effective in improving floc size in combination with ferric chloride, but showed little advantage with the other primary coagulants from limited testing.
- A lower alum dose may be satisfactory in achieving similar settled water turbidity than a higher dose, once optimized for turbidity removal. This could not be verified for the other two primary coagulants or for TOC removal optimization.
- Tapered flocculation with a total mixing energy (Gt) of approximately 68,000 was more effective than constant speed flocculation with a total mixing energy (Gt) of 56,100.
- A lowered pH may improve the performance of alum. Additional jar testing to confirm the performance of enhanced coagulation is recommended. PACl and ferric chloride were not as effective at a lower pH.
- The TOC removal requirements ranged from 15 to 35 percent. TOC removal was measured between 20 and 30 percent in the second and third testing periods, meeting the requirements for that period. However, none of the coagulants were able to achieve the 35 to 40 percent removal percentage that may be required during some periods throughout the year. Testing of enhanced coagulation was not optimized for TOC removal.
- The settling data collected confirmed a typical sedimentation loading rate of 0.5 to 1.0 gpm/sf will be adequate.

The range of optimum chemical doses determined during testing are presented in Table 2-10.

Table 2-10. Range of Optimized Chemical Doses[1]

Chemical	Dose Range, mg/L
Pre-Oxidant	0.5 – 1.0
Alum	14 – 30
Ferric Chloride	7 – 35
PACl	3 – 4 [2]
Coagulant Aid	0.5 – 2.0
Flocculant Aid	0.25 – 0.5

[1]Chemical doses were optimized for turbidity removal but not for TOC removal.
[2]The potential high end dose was not determined as the testing during the first round was unsuccessful.

2.6.2 Requirements

In a conventional treatment plant, the purpose of using chemicals such as coagulants and polymers is mainly to coagulate and settle solids from the raw water and provide better filter performance. The chemicals used must be compatible with the water characteristics, cost effective, and reliably available. Additional considerations include safety and operator preference.

Because of the varying raw water conditions, the chemical feed systems must be flexible for applying a varying range of doses and chemicals, potentially at several application points as conditions dictate. Periodic jar testing and monitoring of the raw and other source water will be necessary for the proper control of the plant operations. In addition, the range of chemical dosing, as provided by chemical feed equipment, must provide a wide range to meet varying water quality. The plant facilities must provide these flexibility requirements.

2.6.3 Identification of Process Chemical Alternatives

A wide range of chemicals are used in water treatment. Each chemical has advantages and disadvantages and may or may not be appropriate and effective for the Rio Grande water quality. Many chemicals were tested in the bench-scale testing portion of the project to assess whether the chemical is suitable for the source. Table 2-11 presents the toolbox of options for primary coagulants that can be utilized for evaluation and selection of the process chemical alternatives.

Table 2-11. Primary Coagulant Toolbox of Options

Toolbox Option[1]	Recommended Dose	Applicable to MRC WTP Design?
Ferric Chloride	7 to 40 mg/l	Yes, slightly more expensive than alum. Commonly used for drinking water coagulation. May not require pH adjustment for enhanced coagulation.
Ferric Sulfate	NT	Yes, slightly more expensive than alum. Commonly used for drinking water coagulation.
Aluminum Sulfate (Alum)	14 to 40 mg/l	Yes, most common and inexpensive conventional coagulant. Requires pH adjustment for enhanced coagulation.
Acidified Alum	NT	Yes, combines an acid with alum to depress pH for enhanced coagulation with one chemical feed system. Allows less operator control of pH independent of alum dose.
Polyaluminum Chloride (PACl)	3 to 13 mg/l	Yes, two times more expensive than alum, however requires one third to one fourth the dose and produces less solids. Proper formulation selection required.
Dual coagulant (PACl and Ferric or Alum)	See above	Yes, provide dual storage for feeding either PACl and ferric or alum according to raw water quality, TOC removal requirement, and most cost-effective coagulant.

[1]Chemical treatments during jar testing included potassium permanganate, cationic coagulant aid polymer, and non-ionic flocculent aid polymer.
NT – Not tested during bench scale testing.

All of the tested coagulants were able to achieve respectable settled water turbidities under 1 NTU. Testing of the TOC removal percentages achieved during two of the rounds and the varying performance of each coagulant during the different rounds may necessitate the provision of a two coagulant chemical feed system. Two systems will allow the operators to switch the coagulants during the year to respond to extreme conditions. All of the coagulants listed, except PACl, have corrosion related issues that will be discussed further in Section 3.

A pre-oxidant, prior to coagulation, improved the coagulation process in some of the limited bench-scale testing. Typically with water containing a high level of organics, a pre-oxidant improves coagulation and subsequent particle removal, mitigates T&O causing compounds, minimizes algae growth in basins, oxidizes iron and manganese for subsequent removal, and may reduce slime buildup in raw water piping. Table-2-12 lists the pre-oxidant alternatives.

Table 2-12. Pre-Oxidant Toolbox of Options

Toolbox Option	Recommended Dose	Applicable to MRC WTP Design?
Potassium Permanganate	0.5 to 1.5 mg/l	Yes, is a less effective oxidizing agent than chlorine-based chemicals or ozone. Typically fed upstream of the plant to provide sufficient oxidizing time. Does not produce DBPs. Requires on-site mixing of delivered dry chemical with water before feeding.
Sodium Permanganate	0.5 to 1.5 mg/l	Yes, is a less effective oxidizing agent than chlorine-based chemicals or ozone. Typically fed upstream of the plant to provide sufficient oxidizing time. Sodium permanganate fed in liquid form. Does not produce DBPs.
Ozone	NT	Yes, requires on-site ozone gas generation typically using liquid oxygen, injection, contactor basins and off-gas destruction. May have additional benefits: color removal, DBP reduction, and/or improved filtration.
Sodium Hypochlorite	0.5 to 2 mg/L	No, produces significant DBPs. Bulk delivery or on-site generation, also can use MIOX equipment as used at other City facilities. Could be used in combination with chlorine dioxide resulting in less DBPs than if dosed alone.
Chlorine Dioxide	NT	Possible, newer technology uses other chlorine sources (hypochlorite) rather than the traditionally used chlorine gas source to generate the chlorine dioxide. May have additional benefits including T&O reduction, *Cryptosporidium* inactivation, and/or improved filtration.

NT – Not tested during bench scale testing

Chlorine, sodium hypochlorite, and MIOX are not recommended as pre-oxidants since they would increase DBP formation when applied before the TOC concentration is reduced. However, studies in El Paso indicate that when combined with another chlorine-based oxidant, chlorine dioxide forms less DBP. More information must be collected and evaluated to determine the suitability of using chlorine dioxide at the MRC WTP. Raw water ozonation would be a costly alterative but it has numerous benefits and should be evaluated further. Potassium permanganate or sodium permanganate will also be evaluated further for pre-oxidation. Typically these chemicals are most effective when 10 to 15 minutes of contact time can be provided prior to coagulation.

Other process chemicals include cationic coagulant aid polymer, flocculant aid polymer, sulfuric acid or carbon dioxide, filter aid polymer, a pre-oxidant, and a disinfectant. Selection of the polymers was not done during the bench scale testing. Testing and selection of polymers typically occur during pilot testing and during initial operation of the plant and is an ongoing consideration to continually optimize the treatment processes. Most of these chemicals will not be evaluated and compared further in this report. The chemical feed systems will be discussed in Section 3.

2.7 Disinfection/DBP Study Results and Implications

2.7.1 Testing Results

Disinfection/DBP testing and analysis was conducted with the assistance of City of Santa Fe staff as part of this project. Jar-testing was performed on water samples collected from the proposed diversion location. Three discrete samples of settled water from optimized jar tests were then sent off to Colorado State University to be processed using ozone, chlorine dioxide, and chlorine, respectively, for disinfection testing. The results of the analysis are shown in Table 2-13.

Table 2-13. Summary of Initial Dosage and Residual Concentrations for Disinfection Test Runs

Disinfectant	Test Run	Initial Dose Concentration (mg/L)	Residual Concentration (mg/L) at 1.0 min	Residual Concentration (mg/L) at 10.0 min [1]
Ozone	1	1.50	0.74	0.16
	2	1.50	0.82	0.17
	3	2.00	1.27	0.46
	4	1.00	0.42	0.03
	5	1.00	0.40	0.01
Chlorine Dioxide	1	0.50	0.27	0.16
	2	0.75	0.45	0.35
	3	1.00	0.63	0.50
Chlorine (as Sodium Hypochlorite)	1	0.60	0.31	0.14
	2	1.00	0.66	0.40
	3	1.50	1.09	0.75

[1]Residual Concentrations at 10.0 minutes for chlorine were calculated using the trend line equation for each Test Run (refer to Disinfection Testing and Analysis Technical Memorandum, Appendix H in Volume 2).

Demand and decay calculations were performed using the disinfection testing data. The results indicate the thirty-second ozone demand ranged from 0.49 to 0.66 mg/L. The one-minute chlorine dioxide demand ranged from 0.23 to 0.37 mg/L and the one-minute chlorine demand ranged from 0.29 to 0.41 mg/L.

Additional information on the disinfection testing and analysis can be found in the *Disinfection Testing and Analysis Technical Memorandum* included in Appendix H of Volume 2.

After disinfection, chlorine was applied to each sample for simulated distribution system (SDS) testing. A 7-day detention time achieving a 0.5 mg/L chlorine residual at the end of the detention time was used as a conservative measure of DBP formation potential. The results of the SDS analysis are shown in Table 2-14.

Table 2-14. Summary of Laboratory Analyses of Disinfection By-Product Concentrations[1]

Primary Disinfection Process[2]	Total Trihalomethane Concentration (μg/L)	Total Haloacetic Acid Concentration (μg/L)
Chlorine (Sodium Hypochlorite) 1 mg/L, 20 min.	154	89
Ozone 1.25 mg/L, 10 min.	133	72
Chlorine Dioxide 0.75 mg/L, 20 min.	104	67
USEPA Standard[3]	**80**	**60**

[1]Settled water collected after jar tests dosed with 1 mg/L potassium permanganate, 35 mg/L ferric chloride, 1.5 mg/L cationic polymer and 0.25 mg/L non-ionic polymer. Jar tests optimized for turbidity removal but not TOC removal.

[2]Primary disinfectant used followed by 7-day SDS test. Chlorine applied to all samples to achieve 0.5 mg/L chlorine residual.

[3]United States Environmental Protection Agency Stage 1 Disinfectant and Disinfection By-Product Rule Standard.

The results of the analyses conclude that DBP formation was most significant, highest concentration of TTHM and HAA, using chlorine as a primary disinfectant. Ozone produced 14 percent less TTHMs and 19 percent less HAAs than chlorine for this water sample. Chlorine dioxide produced 33 percent less TTHMs and 25 percent less HAAs than chlorine. These results indicate that ozone or chlorine dioxide disinfection should decrease DBP formation for this water.

These samples were conducted with chemical doses that were optimized for turbidity removal but not TOC removal, and therefore could have significant DBP precursors present. An optimized treatment process meeting TOC removal requirements will lessen the DBP formation and allow the use of a chlorine-based disinfectant such as sodium hypochlorite. The use of chlorine dioxide should be studied further, specifically if chlorine and chlorine dioxide have synergistic effects on lessening DBP formation as shown at other facilities.

Additional information on the disinfection by-product study can be found in the *Disinfection By-Product Study Technical Memorandum* included in Appendix G of Volume 2.

2.7.2 Requirements

The Total Coliform Rule (TCR) was promulgated by EPA in June 1989 and applies to all public water systems. The TCR establishes a MCL goal (MCLG) of zero for total coliforms. Coliform concentrations, including *E. Coli* or other various fecal coliforms, may be significantly reduced with disinfection. It is highly likely that the Rio Grande water, the water source for the MRC WTP, will contain *E. Coli* and fecal coliforms because of cattle grazing, effluent from several wastewater treatment plants, and other activities upstream of the diversion. However, the plant must be designed to fully disinfect ambient fecal matter coliforms so it does not enter the distribution system, resulting in TCR violations.

The Stage 1 DBPR added TOC removal requirements dependent upon raw water TOC and alkalinity, lowered the threshold for TOC, established MCLGs and MCLs for disinfection by-products, and set maximum residual disinfectant levels (MRDLs) for disinfectants. Systems must monitor and control the use of disinfectants and meet new requirements for TTHM, the sum of five HAAs, and bromate and chlorite. MCLs for several DBPs are as follows:

- TTHM - 80 µg/L
- HAA - 60 µg/L
- Bromate - 10 µg/L
- Chlorite - 1.0 mg/L

As with the other regulations, the Stage 1 DBPR requirements affect the selection of the unit processes as well as the design criteria. Free chlorine based disinfectants are unlikely to be selected to comply with this and other regulations. The changing source water quality will require operational flexibility to be designed into the plant to allow for minimization of DBP formation and greater disinfection performance. For flexibility in compliance, it is recommended that the design goal for DBPs be 80 percent of the MCL, or 64 µg/L for TTHM and 48 µg/L for HAA. Additional testing should evaluate the formation of DBPs by various disinfectants in water optimized for TOC removal to determine if the design goals are obtainable.

The proposed Stage 2 DBRP was published in the Federal Register on August 18, 2003. The comment period closed on January 16, 2004 with the rule likely being finalized in early to mid-2005. The Stage 2 DBPR will supplement other regulations by requiring systems to meet DBP MCLs at each monitoring site in the distribution system, rather than in the system as a whole based on a running annual average (RAA). This rule requires that the selected disinfectant(s) used at the MRC WTP be carefully chosen to not cause compliance problems with the portion of the distribution system served by this facility.

There are two separate and distinct disinfection processes, primary and secondary. Primary disinfection inactivates microbial pathogens within the water treatment plant, while secondary disinfectants are added to ensure adequate residual disinfection throughout the water distribution system. If a primary disinfectant does not provide an adequate chlorine residual, a secondary disinfectant is required.

Per the Surface Water Treatment Rule (SWTR), all surface water supplies are required to be filtered unless certain exception criteria can be met. With respect to disinfection, the exception criteria state that a water purveyor must demonstrate that the system meets the following primary and secondary disinfection requirements:

- 99.9 percent (3.0-log) inactivation and/or removal *Giardia* lambia cysts;
- 99.99 percent (4.0-log) inactivation and/or removal of viruses;

- Application of the "CT" concept (CT is defined as the product of the exposure time "T" (in minutes) and the concentration of disinfectant "C" (in mg/L) measured during peak hourly flow periods).
- Residual disinfectant concentration in the water entering the distribution system cannot be less than 0.2 mg/L for more than four hours (target chlorine residual leaving MRC WTP is 1.5 to 3.0 mg/L);
- Residual disinfectant concentration (as total chlorine) cannot be undetectable in more than five percent of the monthly samples for any two consecutive months;

Per the Bin Classification required by the LT2ESWTR discussed in Section 2.2, an additional 1.0-log removal/inactivation of *Cryptosporidium* is recommended at the MRC WTP. The toolbox of options (Table 2-3) identified ozone and UV as primary disinfection options to meet the requirements with the credit based on the CT table.

Since conventional treatment may be used at the MRC WTP, filtration and primary disinfection must provide at least 0.5-log *Giardia* removal/inactivation, 2.0-log virus removal/inactivation, and an additional 1.0-log *Cryptosporidium* removal/inactivation. The required CT values for the inactivation of *Giardia* cysts and viruses are presented in Table 2-15 for several common disinfectants. UV dosage requirements (in lieu of CT values) are also included in this table, as UV may be utilized for primary disinfection at the MRC WTP.

Table 2-15. Inactivation Requirements for *Giardia*, Viruses, and *Cryptosporidium*

Inactivation Requirement	Disinfection Process						
	Free Chlorine[4] CT Value (mg-min/L)		Chlorine Dioxide CT Value (mg-min/L)		Ozone CT Value (mg-min/L)		UV[5] Dosage Requirement (mJ/cm^2)
	T = 5° C	T = 25° C	T = 5° C	T = 25° C	T = 5° C	T = 25° C	
0.5-log *Giardia* Inactivation [1]	33	8.0	4.3	2.0	0.32	0.08	1.5
2.0-log Virus Inactivation [2]	4.0	1.0	5.6	1.4	0.60	0.15	100
1.0-log *Cryptosporidium* Inactivation [3]	N/A	N/A	429	75	16	2.5	2.5

N/A: Not Applicable

[1]Assume 2.5-log of required 3.0-log inactivation met by conventional treatment.
[2]Assume 2.0-log of required 4.0-log inactivation met by conventional treatment.
[3]Assume additional 1.0-log inactivation required by Bin 2 Classification.
[4]Assume 2.0 mg/L free residual at pH 7.5.
[5]UV dosage requirements are independent of temperature.

Sources:
- *"Draft Ultraviolet Disinfection Guidance Manual"* (EPA, June 2003).
- *"Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources"* (American Water Works Association, October 1990).
- *"Long Term 2 Enhanced Surface Water Treatment Rule, Toolbox Guidance Manual"* (EPA, June 2003).

Required CT values vary with temperature: a colder water results in higher CT values because it is harder to inactivate microorganisms at colder temperatures. UV will not be efficient with virus inactivation/removal due to the high dosage requirement. Therefore a chemical disinfectant will be required for virus inactivation. Ozone is the most efficient chemical. Free chlorine and chlorine dioxide have similar CT values for virus inactivation but chlorine dioxide is significantly more efficient for *Giardia* inactivation.

2.7.3 Identification of Process Alternatives

Table 2-16 presents a toolbox of primary and secondary disinfection and DBP control options.

Table 2-16. Primary and Secondary Disinfection and DBP Control Options

Process Options	Disinfection Process Issues	DBP Formation Issues	Applicable to MRC WTP Design?
Primary Disinfection			
Chlorine	High CT for primary disinfection.	High DBP formation	No, significant safety concerns and regulatory requirements. Gaseous chlorine not recommended for MRC location.
Chlorine Dioxide	Chlorite by-product MCL = 1 mg/L limits chlorine dioxide dose. Used as primary disinfectant. No distribution residual, therefore need secondary disinfectant.	Lowest DBP formation potential of disinfectants tested. May reduce DBP formation when used in conjunction with chlorine.	Possible, newer technology uses other chlorine sources (hypochlorite) rather than the traditionally used chlorine gas source to generate the chlorine dioxide. More efficient than chlorine for *Giardia* inactivation. May have additional benefits including T&O reduction, iron and manganese reduction, and/or improved filtration.
Ozone	Strongest disinfectant available with lowest CT. No distribution residual, therefore need secondary disinfectant.	Lower THM and HAA formation potential than chlorine but does produce bromate.	Yes, requires on-site ozone gas generation, injection, contactor basins, and off-gas destruction. May have additional benefits including T&O reduction, color removal, and improved filtration.
UV	CT significantly less than chlorine. Very effective disinfectant for *Giardia* and *Cryptosporidium*. Ineffective for viruses and produces no distribution residual, therefore need additional disinfectant.	No DBP formation.	Yes, requires pipes and valves for UV light modules.
Sodium Hypochlorite	High CT for primary disinfection.	High DBP formation.	Yes, used at other City facilities. CT can be met in large clearwell. Used for secondary disinfection after TOC reduction to minimize DBP formation.
Secondary Disinfection			
Chlorine	Easily applied for disinfection residual	When used for secondary disinfection after TOC reduction would minimize DBP formation.	No, gaseous chlorine not recommended for MRC location.
Chloramines	Entire distribution system requires conversion for chloramines residuals due to incompatibility with chlorine residuals.	Chloramines residual should result in lower DBP formation potential than chlorine.	No, for chloramines residual, entire distribution system would require conversion.

Table 2-16. Primary and Secondary Disinfection and DBP Control Options

Process Options	Disinfection Process Issues	DBP Formation Issues	Applicable to MRC WTP Design?
Sodium Hypochlorite	Easily applied for disinfection residual	When used for secondary disinfection after TOC reduction would minimize DBP formation.	Yes, used at other City facilities. When used for secondary disinfection after TOC reduction in would minimize DBP formation. May be used synergistically with chlorine dioxide.

For primary disinfection, all but chlorine are potentially applicable for the MRC WTP. Chlorine is eliminated from further consideration because of safety concerns, as discussed previously. Although chlorine dioxide has many benefits and is a more efficient disinfectant than chlorine, there is inadequate information to determine it's suitability for this water source at this time. Ozone, UV and sodium hypochlorite will all be evaluated further as a primary disinfectant. Chlorine dioxide should be further evaluated through future bench-scale or pilot testing.

Sodium hypochlorite is the only secondary disinfectant recommended for the MRC WTP. Chlorine is eliminated as discussed in the previous paragraph. Chloramines are not being carried forward for additional analysis since the use of chloramines would require conversion of all other City facilities for compatibility purposes.

2.8 Corrosion and Blending Study Results and Implications

2.8.1 Testing Results

In drinking water treatment, water quality characteristics and chemical dosage requirements must periodically be monitored to prevent excessive corrosion and scaling in piping systems. For the corrosion and blending evaluation, Rio Grande water and Buckman Well Field waters (Wells 1 through 13) were analyzed utilizing an equilibrium chemistry program developed specifically for drinking water purposes. With the assistance of the *Rothberg, Tamburini and Winsor (RTW) Model for Water Process and Corrosion Chemistry*, water chemistry associated with precipitation/coagulation and the corrosion and scaling potential of water was analyzed. Results of the analyses concluded that Rio Grande water, if properly conditioned, will be no more or no less problematic than the Buckman Well water. Periodic evaluation and monitoring of water quality characteristics and chemical dosages should be performed during operation of the MRC Water Treatment Plant to prevent excessive corrosion and/or scaling conditions when blended with other water sources.

The main consideration for the modeling was the corrosion potential, as based primarily on the Langlier Saturation Index (LSI) and the Ryznar Index (RI). Other characteristics, including alkalinity, pH, precipitation potential (PP), and aggressiveness index (AI) were compared.

LSI is a measure of the scaling potential of a water source. Scaling is caused by the accumulation of calcium, TDS, and bicarbonate. LSI is the difference between the actual pH of the water and the pH at which scaling occurs. A slightly positive LSI indicates that scaling may occur producing a protective layer between the pipe and the water that may limit corrosion. A LSI just slightly positive (e.g., 0.5) provides the benefit of slight scaling (such as development of a protective coating) without the adverse effects of excessive scaling. Conversely, with a negative LSI, $CaCO_3$ is dissolved and the water tends to become corrosive. A slightly negative LSI (-0.5 to 0) may have no adverse impact.

RI is similar to LSI in that it determines the scaling potential of the water. The RI is equal to two times the pH at which scaling occurs, minus the actual pH. An RI of 6 or less is most desirable and an RI of 8 or more indicates corrosion may be pervasive. In between 6 and 8, slight corrosion may occur but it may not cause problems in the system.

PP indicates the potential for calcium carbonate precipitation (scaling) to occur. A negative value indicates no scaling will occur and that the water is aggressive and may be corrosive.

AI indicates how quickly corrosion will take place. AI values between 10 and 12 are considered slightly or moderately aggressive while water with an AI greater than 12 will not be aggressive to exposed surfaces.

For this study, the RTW model was utilized to analyze five distinct scenarios for the Buckman Direct Diversion Project. The modeling and/or blending scenarios are briefly described below:

- Scenario 1: Baseline evaluation of Buckman Wells 1 through 9 to determine if the current conditions promote corrosion or scaling. The characteristics for the well water calculated in this scenario served as the modeled characteristic “goals” for the treated water from the MRC WTP.
- Scenario 2: The raw water, collected from the proposed location of the Buckman Intake Structure on the Rio Grande was modeled. Assuming the raw water continuously flows through ductile iron (DI) pipe, the potential for corrosion or scaling was analyzed as a single source.
- Scenario 3: The raw Rio Grande water treated at the MRC WTP and blended with water from Buckman Wells 10 through 13.
- Scenario 4: The treated water from the MRC WTP was blended with the water from Buckman Wells 1 through 9.
- Scenario 5: The treated water from the MRC WTP was blended with water from Buckman Wells 1 through 13.

A large number of modeling runs were completed to determine the affects of the various raw water quality through the season, varying water quality characteristics in the Buckman Wells, blending ratios, and chemical dose changes. Because blending of the treated water with the Buckman Wells is the focus of this study, the initial modeling (scenario 1) concentrated on defining the water quality as currently seen in the Buckman system (mainly Wells 1 through 9). The chemical doses used for treatment (Scenario 3) were devised to match the Buckman Well quality. A range of the characteristics determined from the modeling results are shown in Table 2-17.

Table 2-17. Summary of Characteristic Ranges from Modeling Scenarios

Characteristic	Buckman Wells 1-9	Raw Rio Grande	Treated Water [1]	Treated Water Blended with Buckman Water [2]
Alkalinity	179 to 657 mg/L	100 to 100 mg/L	111	164
pH	6.8 to 8.3	7.2 to 8.03	7.58	7.58
PP	-11.45 to 44.70	-10.14 to 22.10	-1.24	-8.49
LSI	-0.46 to 0.29	-0.45 to 1.28	-0.06	-0.36
RI	6.5 to 8.8	6.33 to 8.11	7.71	8.3
AI	11.3 to 12.1	10.72 to 12.64	11.2	11.4

[1]Treatment consisting of 21 mg/L ferric chloride, 13 mg/L sodium hydroxide, 1 mg/L hydrofluosilicic acid and 1.5 mg/L sodium hypochlorite.
[2]68% treated water (see note 1 for chemicals and doses) blended with 32% from Wells 2-5, 10 and 11 (high concentration wells).

The modeling showed that Wells 3, 5, and 9 are the only wells of the 13 that precipitate rather than corrode. All other wells have a negative LSI and PP. The raw Rio Grande water will alternate between the potential to corrode or precipitate through the year as the raw water quality changes. The MRC WTP can tolerate these changes but design of the raw water pipeline will have to ensure the pipeline can withstand these changes.

Treatment of the raw water at the MRC WTP considered the use of alum or ferric chloride, sulfuric acid or carbon dioxide (to depress the pH), caustic soda (sodium hydroxide) or soda ash (to raise the pH), hydrofluosilicic acid and sodium hypochlorite in various combinations. In all cases, the water quality of the Buckman Wells could be matched through the control of the finished water pH with the addition of either sodium hydroxide or soda ash. When blended, the blending ratios and specific wells in operation had little impact on the water characteristics.

Details of this study can be found in the *Corrosion and Blending Study* technical memorandum included in Appendix I of Volume 2.

2.8.2 Requirements

If the water characteristics and conditions are right, the water in the distribution system can corrode the metal piping resulting in elevated concentrations of metals, including lead and copper, in the drinking water. The Lead and Copper Rule (LCR) set action levels of 0.015 mg/L and 1.3 mg/L for lead and copper, respectively. Treatment requirements could be triggered if more than 10 percent of the samples exceed one or both of the action levels.

Because of the multiple water sources with varying water characteristics, introduction of a new water source into the system has the potential to disrupt the distribution system and exceeding the action levels. Design of the MRC WTP must address the impacts on the distribution system from blending the water sources to minimize corrosion and or precipitation in the distribution system through the production of treated water compatible with the other sources.

Based upon the RTW modeling completed as part of the blending and corrosion study, the following conclusions regarding the requirements to properly condition and blend the water can be made.

1. pH adjustment of the MRC WTP's finished water is necessary to match the water quality of the Buckman Wells.

2. Proper monitoring of the pH adjustment chemical dose will be necessary during operation so the blended water conditions do not alternate between corrosive and precipitating.

3. Carbon dioxide is more efficient for use in enhanced coagulation with alum because it minimizes the consumption of alkalinity compared to sulfuric acid. However, carbon dioxide doses are quite high for highly buffered waters.

4. Use of sodium hydroxide and soda ash both produce water of quality compatible with Buckman well water.

5. The Buckman Direct Diversion raw water pipeline design must tolerate both corrosive and scaling environments.

6. Additional testing is necessary to adequately evaluate blending of the treated water with all Santa Fe water sources, including the City Wells and Canyon Road WTP.

Additional recommendations were presented in report titled *Buckman Direct Diversion (BDD) Water Treatment and Blending Analysis* prepared by EE&T in September 2004.

EE&T performed additional blending and corrosion analyses that are discussed in the report *Buckman Direct Diversion (BDD) Water Treatment and Blending Analysis.* The study also determined that blending and corrosion control could be adequately performed by adjusting finished water to a pH of 7.4 and matching the characteristics of the other water sources. EE&T also recommended the use of a corrosion inhibitor such as zinc orthophosphate.

2.8.3 Identification of Process Alternatives

When blending different source waters, there are two major concerns. The first is matching the water qualities to prevent alternating conditions within the pipelines causing scaling and corrosion of the scale. These changing conditions were the cause of the problems experienced by Tucson and their Central Arizona Project WTP.

Adjustment of the pH and alkalinity through various chemicals provide the control to match the water qualities. The second issue is prevention of corrosion within the distribution system resulting in LCR compliance issues. Table 2-18 presents the corrosion and blending toolbox of options for use in selecting the appropriate options for further evaluation.

Table 2-18. Corrosion and Blending Toolbox of Options

Issue	Process Options	Applicable to MRC WTP Design?
Corrosion	Chemical sequestering agent	No, inadequate information on the need of chemical or the resulting impact on the rest of the system.
	Corrosion inhibitor	No, inadequate information on the need of chemical or the resulting impact on the rest of the system.
pH Adjustment to Match Existing Distribution Water and Prevent Pipeline Corrosion	Sodium hydroxide to pH>7.5	Yes, inject into clearwell to raise pH to prevent corrosive conditions and match distribution water quality. Liquid chemical.
	Soda ash to pH>7.5	Yes, inject into clearwell to raise pH to prevent corrosive conditions and match distribution water quality. Dry chemical.

The use of either pH adjustment chemical was modeled and both are capable of producing finished water of the quality needed to blend with the Buckman wells. Sodium hydroxide typically is fed at a lower dose than soda ash. Soda ash adds significantly more alkalinity to the water than does sodium hydroxide. One is a dry chemical (soda ash) and the other is a liquid chemical (sodium hydroxide). Both chemicals will be evaluated further in Section 3.

Although the goal of the treated water was to match the Buckman water, it is not known if the Buckman well quality already is problematic with certain other waters. Other limited studies evaluated blending of the City's other water sources. Although the limited study determined that blending could be done successfully with proper monitoring and pH control. The study did recommend coupon studies to evaluate corrosion control characteristics and the need for a phosphate-based corrosion inhibitor. If corrosion is a problem in the system such that a corrosion inhibitor would be beneficial, the corrosion inhibitor may have to be installed at other facilities, such as the 10-million-gallon tank. The use of a corrosion control system will not be carried forward because of the lack of data to accurately evaluate the need and effect of these options. However, it is agreed that additional studies should include an evaluation of the implementation of a corrosion control system throughout the water system. It is recommended that a spare chemical storage and feed system be included in the plant design that could be used for full scale testing of corrosion control chemicals. Additional blending scenarios may be beneficial to evaluate the range of water conditions for all water sources and the resulting potential for problems within the distribution system.

2.9 Presedimentation Study

Sedimentation facilities are proposed near the river to protect the pumping equipment from sand and grit. The inlet within the river will be constructed of screens with 2-mm openings. The sedimentation facility will be designed to remove all sediment larger than 0.1-mm to 0.3-mm. As part of the water quality evaluation, the water collected from the river was filtered with screens having 2-mm and 0.3-mm openings. The water collected from the river was not from the bottom of the river and was not as sediment-laden as what may collect in the constructed inlets. Very little sediment was collected on either screen during the testing. Sand and grit dropped out of both of the samples nearly immediately and does not contribute significantly to the turbidity. During the third round of testing, turbidity was monitored over time in the raw water and screened water. The samples were placed in the jar testing beakers and water was drawn off from the sample port located 10-cm below the water surface at noted time intervals. The turbidity of each sample was measured and recorded. The collected data is shown in Table 2-19.

Table 2-19. Presedimentation Results

Parameter	Time, Minutes							
	0	1	3	8	11	21	36	66
Raw settling velocity, cm/min		10.00	3.33	1.25	0.91	0.48	0.28	0.15
Raw loading rate, gpm/sf		2.50	0.83	0.31	0.23	0.12	0.07	0.04
Raw Water								
Turbidity, NTU	25	17	17	14	14	13	12	11
Raw % turbidity remaining	100	68	68	56	56	52	48	44
Screened Water								
Turbidity, NTU	25	19	21	20	21	18	20	17
Screened % turbidity remaining	100	76	84	80	84	72	80	68

The initial turbidity was 25 NTU in the two samples. The turbidity measurements in the raw water (not filtered through the two screens) dropped consistently over time. However, the turbidity of the screened water did not follow this pattern as expected. The cause of this unexpected pattern is unknown but ongoing problems with the laboratory turbidimeter could be to blame. The difficulty of keeping the sediment suspended while filling the jar testing beakers could have further led to the unexpected results.

The results did indicate that presedimentation at the river would be effective in removing 32 to 56 percent of the turbidity. This reduction in turbidity will translate into considerable removal of suspended solids at the near-river sedimentation facilities and at the solids separation processes at the water treatment plant. These solids could be put to beneficial use, although that use needs to be identified. Additional presedimentation evaluations would be helpful during future bench-scale or pilot testing activities.

Section 3
Process Alternatives and Analysis

3.1 Overview of Process Selection

This section provides a review and evaluation of various processes and equipment for meeting treatment goals presented in Section 2. Table 3-1 provides a summary of treatment criteria and goals that were established through an evaluation of regulations, bench-scale testing and laboratory testing.

Table 3-1. Treatment Criteria and Goals for Process Evaluation and Selection

Category	Criteria/Goal	Process Selection Considerations
Treatment Requirements for *Cryptosporidium*	▪ 2.0-log *Cryptosporidium* removal/inactivation through conventional treatment with 0.3 NTU in 95% of filtered water samples, never exceeding 1.0 NTU ▪ 1.0-log additional treatment from Bin 2 classification	Affects selection of coagulation, sedimentation, filtration, disinfectants, and chemicals. Additional 1.0-log treatment through toolbox options presented in Table 2-3.
Taste and Odor	▪ Iron and manganese removal below 0.1 mg/L and 0.05 mg/L respectively. ▪ Reduce levels of other T&O causing compounds including NOM, TDS and potentially SOCs. ▪ Mitigate algae blooms in source water and algae growth in process units.	Affects selection and use of preoxidant, coagulation, sedimentation, filtration, and chemicals. Toolbox options presented in Table 2-4.
Contaminants	▪ Turbidity: 0.1 NTU ▪ Color: 12 pt Co units ▪ Aluminum: 40 µg/L ▪ Arsenic: 8 µg/L ▪ Manganese: 40 µg/L ▪ Nitrate: 8 mg/L	Affects selection of coagulation, sedimentation, filtration, preoxidant, management of raw and finished waters, and possible selection of other processes such as ion exchange, membranes, and other units. Toolbox options presented in Table 2-7.
Organics and TOC Removal	Required: ▪ 25% to 35% in winter months ▪ 35% to 40% in non-winter months ▪ Annual average TOC removal of 33% ▪ Annual average of high TOC removal 37% Treatment Goal: annual average of 42% TOC removal or finished water TOC of <2 mg/L	Affects selection of coagulation, sedimentation, filtration, preoxidant, and possible selection of other processes such as MIEX, GAC contactors, etc. Toolbox options presented in Table 2-9.
Chemical Application	▪ Pre-Oxidant Dose - 0.5 to 1 mg/L ▪ Coagulant Dose - 3 to 40 mg/L ▪ Coagulant Aid Dose - 0.5 to 2 mg/L ▪ Flocculant Aid Dose - 0.25 to 0.5 mg/L ▪ pH adjustment chemicals, filter aid polymer, solids thickening polymer also needed at varying doses	Affects selection and design of chemical feed systems and solid handling facilities. Toolbox options presented in Tables 2-11 and 2-12.
Primary Disinfection	▪ 0.5-log *Giardia* removal/inactivation ▪ 2.0-log virus removal/inactivation ▪ additional 1.0-log *Cryptosporidium* removal/inactivation	Removal and inactivation through filtration, disinfection and/or an additional process. Options presented in Table 2-16.
Secondary Disinfection	▪ Target residual of 1.5 to 3.0 leaving WTP ▪ THMs < 64 µg/L ▪ HAAs < 48 µg/L	Required to meet minimum residual requirements in distribution system. Options presented in Table 2-16.

Table 3-1. Treatment Criteria and Goals for Process Evaluation and Selection

Category	Criteria/Goal	Process Selection Considerations
Corrosion and Blending	▪ pH>7.5 to meet LCR Match distribution system conditions, which are approximately: ▪ LSI of -0.5 to 0.5 ▪ RI of 6 to 8 ▪ PP <0 ▪ AI>12	Adjustment of finished water pH, and possibly alkalinity, through options presented in Table 2-18.

Section 2 provided a number of treatment options for meeting the goals and criteria shown in Table 3-1. Some of these options were screened out within Section 2 and will not be considered further within this section. The objective of selecting a process train is to provide the City with a treatment facility that meets treatment goals and can be used for further project planning purposes such as cost estimating and scheduling. As part of the scope of work for this task, it is assumed that a preliminary design will be prepared to further refine the processes and equipment in meeting treatment goals and possibly provide a more cost-effective approach.

As part of this project, workshops were held with the City's operations and maintenance staff to report progress and findings, and to receive input into the MRC WTP facilities. Table 3-2 provides a list of items that the City would like considered as this project progresses. It is anticipated that the City will provide even more input as the project moves through preliminary design to tailor facilities to their specific needs.

Table 3-2. City Requested Items for Consideration in Evaluation of MRC WTP Facilities

MRC WTP Facility/Area	Items for Consideration
Plant Site	▪ Paved roadways to and around facilities ▪ Adequate signage including impressive facility sign ▪ Landscaping trimmed with Waldo Turquoise crushed gravel ▪ No gravel walkways ▪ Xeriscape landscaping with temporary irrigation to establish plants ▪ Perimeter lighting, electric gate with key pad, security fencing and surveillance cameras ▪ Plant water to come from Clearwell storage tank discharge ▪ One day minimum treated water storage on site
Administration Building	▪ Receptionist desk and area ▪ At least six offices, minimum 15' x 15' with windows ▪ Computers and printers for each office, as well as two central fax machines ▪ Laundry facilities, break room, locker rooms, supply closet, conference/training room ▪ Intercom system throughout facilities ▪ Maintenance shop with at least 4 work areas ▪ Supply facility, minimum 40' x 40', with roll-up doors ▪ Refrigerated air throughout facility ▪ No skylights due to possible leakage problems
Plant Laboratory	▪ Minimum 25' x 25' working area ▪ 3 sinks, double counter spaced ▪ Supply closet ▪ Sampling of all processes ▪ May not want certified laboratory, for process analysis only

Table 3-2. City Requested Items for Consideration in Evaluation of MRC WTP Facilities

MRC WTP Facility/Area	Items for Consideration
Monitoring & Control	▪ SCADA system for monitoring of all tank levels, equipment status, and analyzers ▪ Report generating feature connected with SCADA ▪ Control of all pumps and other critical equipment ▪ Manual and automatic control capabilities ▪ Consistency with current equipment and systems ▪ Monitoring and control of remote facilities including wells, and possibly Canyon Road WTP monitoring
Coagulation, Flocculation & Sedimentation	▪ All mixers and scrapers on VFDs ▪ Progressive cavity or rotary lobe pumps for sludge removal ▪ Analyzers within processes possibly including pH and TSS meters in reaction zone, sludge blanket indicators, sludge density meter, as wells as standard equipment for chlorine residual, temperature, flow meters, etc. ▪ Automatic blowdown on sludge basins ▪ Adjustable weirs in processes ▪ Torque overload on scrapers ▪ Automatic adjustable influent flow control ▪ Motorized sluice gates for flow splitting ▪ Possible use of circular upflow contact clarifiers ▪ Good spare part supply and inventory ▪ Waste streams to be monitored with flow metering, density meters on blowdown, and TSS and pH meters on recycled water ▪ No belt drives
Filtration	▪ Individual PLCs for filter control panels ▪ Filter underdrain with MIS cap and air/water backwash ▪ Filter Backwash tank in lieu of high rate backwash pump from Clearwell ▪ Do not fill backwash tank from Clearwell due to effect on CT and turbulence ▪ At least 2 extra filters; minimum 33% redundancy to meet peak flow ▪ Particle counters and turbidimeters on individual filters and combined
Possible Technologies	Consideration should be given to other processes, such as: ▪ MIOX disinfection ▪ UV or UV in series with MIOX ▪ MIEX for TOC removal along with conventional treatment ▪ Addition of lime to increase alkalinity
Chemical Facilities	▪ All chemical to be liquid form ▪ Do not use potassium permanganate, hard to dissolve ▪ Adequate room in chemical areas and on docks ▪ Overhead crane at dock and forklift ▪ Good gravity feed of chemicals to hard piped metering pumps ▪ Spill containment for chemicals ▪ Monitoring and control of chemicals including low level indication in tanks, electronic control of metering pumps, etc.

These City requested features have been considered in the screening of alternatives, and for the most part have been followed. In some cases the requests were not met, and will need to be discussed further with the City.

3.2 Presedimentation

3.2.1 Process Overview

Presedimentation typically refers to the impoundment of raw water prior to treatment to remove readily settleable solids, provide a large storage volume in case the intake needs to be shutdown, and/or to allow the supply system flow rate and the plant flow rate to fluctuate independent of each other. In the case of the Buckman Direct Diversion Project, solids larger than 0.3 mm will be removed at the diversion structure and at the solids removal facility (either high rate mechanical solids separation or high rate settling basins) to provide lower maintenance associated with the booster pump stations.

3.2.2 Treatment Options

Presedimentation alternatives for the MRC WTP are shown in Table 3-3. Included in the alternatives is a "no presedimentation" option. These options are specific to a presedimentation facility located at the MRC WTP and are in addition to the presedimentation facility planned for near the river.

Table 3-3. Presedimentation Comparison

Treatment Option	Advantage	Disadvantage
Presedimentation Basins	▪ Provides large volume of raw water at plant to be utilized should the raw water supply system be shutdown. ▪ With coagulant, provides additional removal of solids and lower influent turbidity. Provides 0.5-log credit for *Cryptosporidium* removal.	▪ Large land area required ▪ Allows growth of algae requiring T&O control and additional oxidation. ▪ Large evaporative loses, as much as 5 feet per year.
High Rate Mechanical Separation	▪ Does not require a large area ▪ Small power use process ▪ No loses to evaporation	▪ Redundant, solids of this size already removed at Diversion facilities. ▪ Does not provide storage of raw water.
High Rate Sedimentation Basins	▪ Smaller area required then presedimentation basins ▪ Provides 0.5-log credit	▪ Additional process requiring O&M ▪ Doesn't provide storage of raw water.
No Presedimentation	▪ Does not promote algae growth ▪ No loses to evaporation ▪ No additional land requirement ▪ Lack of raw water storage can be off-set by additional finished water storage ▪ Lower O&M cost	▪ Does not provide raw water storage. ▪ Turbidity removal higher for sedimentation and filtration. ▪ Does not provide 0.5-log credit.

3.2.3 Evaluation and Conclusions

Due to the use of solids separation near the river, presedimentation basins' applicability to the MRC WTP is reduced. Also, due to the need for treated water storage in the City's system, the cost and land area would better be used for providing additional treated water storage. This would allow the plant to be shutdown during extreme poor water quality periods and supply treated water from the finished water Clearwell Reservoir. In light of the advantages and disadvantages discussed in the previous table, it is recommended that the MRC WTP be designed without presedimentation facilities at the plant. In lieu of raw water storage, one day's worth of finished water storage should be provided. Without presedimentation basins, a small surge tank or basin may be needed at the MRC WTP as part of the raw water booster pumping system. This should be addressed during preliminary design.

3.3 Preoxidation

3.3.1 Process Overview

Preoxidation is the addition of an oxidizing agent such as chlorine, ozone or permanganate, to the raw water prior to coagulation. Use of a preoxidant has numerous benefits, as discussed in Section 2, including iron and manganese removal, algae control, more efficient coagulation, some taste and odor mitigation, and slime control in piping.

3.3.2 Treatment Options

There are three preoxidants brought forward from the preliminary screening in Section 2: ozone, potassium permanganate, and sodium permanganate. These are evaluated in Table 3-4.

Table 3-4. Preoxidation Comparison

Treatment Option	Advantage	Disadvantage
Ozone	▪ Good preoxidant ▪ Low DBP formation ▪ Demonstrated benefits in coagulation and filtration ▪ Superior T&O mitigation ▪ Provides pathogen inactivation	▪ High capital and operating cost ▪ Requires air preparation equipment or liquid oxygen, which increases operating costs.
Potassium Permanganate	▪ Demonstrated good preoxidant ▪ Okay algae control ▪ Okay T&O mitigation ▪ Cost effective chemical	▪ Dry chemical which requires batching and constant mixing ▪ Can overfeed without proper safeguards. Best fed sufficiently upstream of plant.
Sodium Permanganate	▪ Demonstrated good preoxidant ▪ Okay algae control ▪ Okay T&O mitigation ▪ Cost effective chemical ▪ Liquid chemical ▪ Staff experienced with use	▪ Can overfeed without proper safeguards ▪ Best fed sufficiently upstream of plant for adequate contact time

3.3.3 Evaluation and Conclusions

Raw water ozonation provides superior plant performance. However, the system is expensive, requires a high degree of maintenance and is complex to operate. Ozone is therefore not recommended for preoxidation.

Potassium permanganate and sodium permanganate have the greatest advantages as a preoxidant without the high costs of ozone. In keeping with the staff's desire to handle only liquid chemicals, sodium permanganate should be used as a preoxidant. In order to help prevent overfeeding, sodium permanganate should be fed upstream of the MRC WTP, possibly off-site at Booster Station 2A. This would provide well over 30 minutes of contact time. Also, analyzers should be used within the treatment train to detect overfeeding of permanganate. Use of PAC or GAC will prevent permanganate from entering the distribution system in a well operated treatment plant. Feeding permanganate upstream in appropriate doses with an analyzer in the plant and maintaining blended water pH in the distribution system would provide the necessary safeguards to prevent a brown water episode as previously experienced downstream of the Canyon Road WTP.

3.4 Coagulation/Rapid Mixing

3.4.1 Process Overview

Rapid mixing is the injection and dispersion of primary treatment chemicals into the raw water stream as part of the coagulation process. This process is extremely important to removing TOC and conditioning the water for sedimentation and filtration. The mixing of chemicals needs to provide a rapid homogeneous dispersion of chemicals since the reaction of the primary coagulant is very rapid, less than one second. Inefficient mixing, such as back mixing or non-homogeneous mixing, results in higher chemical costs and non-optimal coagulation. Of prime importance is the selection and application order of chemicals.

3.4.2 Treatment Options

As discussed in Section 2, and in Volume 2 technical memoranda, the tested primary coagulants provided different results with the varying water quality. Also, the order in which other chemicals were added affects downstream water quality. Table 3-5, provides an evaluation of the various combinations of coagulants.

Table 3-5. Primary Coagulant Comparison

Treatment Option	Advantage	Disadvantage
Acidified Alum	▪ Does not require the use of a pH suppressant for enhanced coagulation	▪ Higher chemical cost ▪ Not tested during bench-scale testing ▪ Less control of process water pH ▪ Dubious results by other water agencies
Aluminum Sulfate	▪ Staff familiar with use of chemical ▪ Provided good coagulation during all three seasons tested ▪ May produce slightly less solids volume than ferric chloride	▪ Requires pH depression to optimize coagulation and provide enhanced coagulation
Ferric Chloride	▪ Performed well during three seasons tested ▪ Provides the best removal of arsenic, should this be needed ▪ Effective over wide pH range, may not require pH depression system ▪ Easier to dry or dewater than other coagulant sludges.	▪ Lower capital and O&M costs compared to pH depression and alum use. ▪ Stains process basins ▪ Mildly corrosive to many materials though less so than low pH water ▪ May produce slightly higher volume of sludge than alum
PACl	▪ Superior performance during portions of the year ▪ Requires much lower dose ▪ Number of different PACl products to choose from	▪ High chemical cost, though off set by much lower required dose ▪ May not be optimal coagulant during parts of the year

In addition to selecting a primary coagulant, the types of other chemicals to be injected during the coagulation step need to be selected. This includes a coagulant aid polymer; and possibly a pH suppression agent (sulfuric acid or carbon dioxide), preoxidant, and PAC.

3.4.3 Evaluation and Conclusions

The three coagulants tested during the three sampling periods showed somewhat similar results. However, the coagulants were not optimized for TOC removal but only for turbidity requirements. Table 3-6 provides estimated chemical costs and sludge production for the three coagulants based upon the turbidity provisions. Additional work has shown that chemical doses will be significantly higher if optimized for TOC removal. The higher doses will increase both the annual chemical cost and the annual sludge production volumes. However, the main component of the sludge is the solids in the raw water and the chemical dose is a very small component of the total volume.

The sedimentation facilities proposed at the river will remove sand and grit larger than 0.1-mm. Work by CH2M HILL indicates that approximately 25 percent of the suspended sediment mass is larger than 0.1-mm. The Draft *Buckman Sediment Management Options Report* concluded that an additional 5 to 15 percent of the sediment load would also be removed in the sedimentation facilities. Therefore, 30 to 40 percent of the sediment load will be removed near the river prior to the MRC WTP. However, the previous studies stated no clear pattern exists between the river flow and the sediment concentration and size. For conservative purposes, this report assumes 30 percent of the sediment is removed at the river. The sludge production values presented in Table 3-6 are based upon average conditions in the river at average flow rates at the plant. At peak flow and worst-case conditions in the river, the daily sludge production could increase dramatically - as high as 220,000 lbs per day. The unpredictability and extreme variability of the sediment concentration will impact the design of the solids handling facilities (near river and at the MRC WTP) likely resulting in conservatively sized facilities.

Table 3-6. Primary Coagulants' Estimated Cost and Sludge Production

Primary Coagulant and Average Dose[1]	Annual Chemical Cost[2] ($1000 per Year)	Annual Sludge Production[3] (Million Pounds Dry Solids per Year)
Acidified Alum 27 mg/L	$56	4.8
Aluminum Sulfate [4] 27 mg/L	$42	4.8
Ferric Chloride 21 mg/L	$48	4.8
PACl 7 mg/L	$24	4.8

[1]Average chemical doses determined through bench-scale testing optimized for turbidity removal (see Appendix F).
[2]Annual chemical costs estimated at an annual average flow rate of 6.2 mgd.
[3]Annual sludge production based on average plant flow rate of 6.2 mgd and average TSS of 342 mg/L, with 30% removed at river. Sludge production estimates are similar due to the high solids loading.
[4]Cost does not include use of pH suppression agent for enhanced coagulation.

Ferric chloride is used at numerous facilities in the western United States. Its performance has been found in most instances to be superior to alum over a wide range of raw water pH and varying water quality. It has been deemed more forgiving to variations in water quality. Although not reflected in Table 3-6, the overall capital and operating cost could be substantially lower than the use of alum since it may not require pH depression upstream. Bench-scale testing performed by EE&T did show an increased TOC removal if the pH was depressed however. Acidified alum has similar characteristics; however, the ability to control pH in the process water is secondary to the required alum dose. High doses of acidified alum could result in several operating issues including too low a pH resulting in corrosion problems, requiring excessive use of sodium hydroxide, and downstream water quality problems (such as solubilizing permanganate from filter media).

Table 3-6 does not discuss a dual coagulant system. Some plants and pilot studies have shown a synergistic effect through a use of two coagulants together. The total coagulant dose with two chemicals may be less than with one chemical alone. This improvement is similar to that shown by the use of a coagulant aid polymer with the coagulant. However, no data is available on the suitability of dual coagulants for this water source. It is recommended that future bench scale or pilot testing include evaluating dual coagulants.

Section 2.4 discussed the possibility of treating Buckman Wells with high concentrations of arsenic and uranium at the MRC WTP. Arsenic is removed through iron-based chemicals such as ferric chloride. Uranium is removed with the use of alum. Because each contaminant requires a different coagulant and these two coagulants are not compatible, the selection of the appropriate coagulant should consider if the MRC WTP will be used to treat any well water. Preliminarily, the arsenic and uranium issues are being handled through operations management and blending of the wells. Therefore, it is recommended that the selection of the coagulant be based upon TOC removal effectiveness and cost. Additional bench scale and pilot testing would be beneficial to determine the required chemical doses for TOC optimization.

However, based upon the currently available information, it is recommended that ferric chloride be used as the primary coagulant. It is also recommended that polyaluminum chloride (PACl) also be used during a portion of the year. This coagulant also showed superior coagulation, especially in cold water, and results in much lower chemical cost. Also, PACl works over a wide pH range and therefore does not require the use of a pH suppression system. Providing two primary coagulants for use during different portions of the year would provide the greatest flexibility for meeting TOC requirements, and removal of arsenic or other contaminants should it be necessary, while responding to changing raw water conditions in the river.

In addition, it is recommended that a preoxidant be added prior to coagulation as discussed in Subsection 3.3. Flocculation and settling were improved when a preoxidant was used with ferric chloride. Though testing was limited and inconclusive, use of a preoxidant showed little to no advantage with alum or PACl. However, a preoxidant has shown to be advantageous at numerous water treatment facilities around the country, it aids in the removal of iron and manganese, and can aid in color and T&O removal.

The bench-scale testing also showed that adding a coagulant aid polymer after the primary coagulant provided superior downstream performance. Though its benefits were not shown in the limited testing conducted, superior performance is usually provided by a delay between primary coagulant addition and polymer addition. This may be due to a conditioning period prior to polymer addition.

The following recommendations are made for the coagulation process:

- Provide for the addition of a oxidizing agent, sodium permanganate, upstream (possibly at Booster Station 2A) of the coagulation process to aid in organics and contaminants removal (and other benefits as noted previously)
- Provide a dual storage and feed primary coagulant system allowing the use of ferric chloride and PACl
- Use a coagulant aid polymer downstream of the primary coagulant, if possible, 15 to 60 seconds after the addition of the primary coagulant

In addition to these recommendations, the coagulation process should include two stages of mixing for primary coagulant addition and coagulant aid polymer addition. Each of these stages should be designed for high energy, efficient chemical dispersion without back mixing. It is also recommended that the use of “colored” concrete, such as a reddish-brown color, be considered during design to mitigate concern with ferric chloride staining of concrete. Material selection for process equipment should be performed with the ferric chloride use in mind.

3.5 Flocculation/Sedimentation

3.5.1 Process Overview

After coagulation, flocculation is the development and agglomeration of flocculated particles (floc). Production of floc prior to sedimentation is important to provide effective settling and good water quality prior to filtration. Sedimentation is the process of either gravimetric settling of the settleable solids or flotation of solids aided by air in order to remove a substantial portion of the solids from the process stream. An efficient flocculation / sedimentation process provides:

- Reduced solids loading of filters
- Reduces the use of backwash water and generation of waste washwater
- Extends the life of GAC in filter absorbers

Bench-scale testing demonstrated that a good settleable floc is provided through the use of proper coagulation.

3.5.2 Treatment Options

Numerous technologies are used in the water industry for removal of particles prior to filtration. Table 3-7 provides a comparison between the various viable options.

Table 3-7. Flocculation/Sedimentation Comparison

Treatment Option	Advantage	Disadvantage
Conventional (Rectangular) Flocculation and Sedimentation	▪ Tapered flocculation shown to be beneficial ▪ Greater control of flocculation with VFDs ▪ Conventional sedimentation basins provide good robust treatment ▪ Can select equipment that is corrosion resistant	▪ Can require substantial space, though two-tray basins, plate settlers or tube settlers can be used to enhance setting and shorten basins ▪ Need to select sludge removal equipment carefully to avoid higher O&M costs ▪ Need to protect basins from effects of wind
Dissolved Air Flotation	▪ Provides higher TOC and color removal ▪ Low settled water turbidity ▪ Smaller footprint compared to conventional basins ▪ May provide 2.0 to 4.0 log *Cryptosporidium* removal	▪ Difficult to operate with heavy floc or with very turbid waters ▪ Operates well with cooler waters, less so with warm waters ▪ Higher maintenance, particularly with aggressive and/or low pH water ▪ Higher power use and coagulant dose resulting in higher O&M costs ▪ Need to select sludge removal equipment carefully to avoid higher O&M costs
Ballasted Flocculation (such as Actiflo™)	▪ Smaller footprint compared to conventional basins ▪ Suited for rapidly fluctuating water quality ▪ Effectively treats very high turbidity source water ▪ Slightly lower capital cost than conventional treatment ▪ May allow for filters to operate at higher filtration rates if floc settling is more efficient	▪ Microsand loss which needs replacement ▪ Typically requires higher polymer doses ▪ Higher power demands ▪ More mechanical equipment increasing O&M requirements ▪ Higher O&M complexity compared to conventional treatment ▪ Less time to react to process problems ▪ Filter runs may be shorter than with conventional treatment ▪ Proprietary equipment ▪ Need piloting with varying water quality to determine if applicable treatment process
Upflow Contact Clarification	▪ City staff familiar with process ▪ Smaller footprint compared to conventional basins ▪ Sludge easily removed	▪ Flocculation process within clarifiers is typically less than optimal ▪ Relies on production and stability of sludge blanket within clarifier ▪ Mechanism susceptible to corrosion ▪ Startup requires sludge blanket formation ▪ Poor hydraulic efficiency (i.e., short circuiting problems) ▪ Susceptible to turnover and efficiency impacted by temperature fluctuations including diurnal changes ▪ Cannot tolerate hydraulic or solids shock loadings ▪ Low solids percentage in sludge requiring larger sludge facilities

3.5.3 Evaluation and Conclusions

Dissolved Air Flotation and Ballasted Flocculation are not recommended for the MRC WTP. These types of process have high maintenance costs, relatively higher operating complexity, and may not be appropriate for the high solids loading and variable water quality that the MRC WTP will need to treat. Upflow Contact Clarifiers are a process that the City is familiar with through its use at the Canyon Road WTP. However, the Rio Grande water is more turbid and has a significantly higher TOC level. To provide a more reliable settling process that does not rely on development of a blanket, rectangular sedimentation basins are recommended. Rectangular basins are more flexible and respond easier to variations in water quality. Sludge removal from the basins can be performed with several types of equipment, including chain and flight, reciprocating scrapers, or hydraulic vacuum systems. It is recommended that sludge removal options be evaluated and discussed with City staff during preliminary design.

3.6 Filtration

3.6.1 Process Overview

Filtration is typically termed as the further reduction of particles through the use of adsorption onto a media. However, with the current and future state of water quality concerns and regulations, filtration is expected to not only remove particulate matter and reduce turbidity, but assist in the removal of:

- TOC
- Color causing constituents
- Contaminants such as SOCs and VOCs
- T&O causing compounds
- Pathogens, such as viruses, *Giardia* and *Cryptosporidium*

These goals can be accomplished through a number of, or a combination of, processes utilizing various technologies.

3.6.2 Treatment Options

Due to the number of treatment options, and the use of upstream and downstream processes that affect filtration or accomplish the goals of filtration, it is necessary to look at combinations of treatment. Table 3-8 lists the treatment options, and their advantages and disadvantages. Section 2 includes other technologies, such as two-stage filtration and membranes, which were dropped from further evaluation. In all cases, gravity filtration was selected for further evaluation since the City's O&M staff is familiar with the process through operation of the Canyon Road WTP, it provides good finished water quality and is cost effective.

Table 3-8. Filtration and Other Processes Comparison

Treatment Option	Advantage	Disadvantage
Gravity Filtration with Anthracite	▪ Lowest cost option ▪ Can operate in biologically active filtration mode for some additional TOC removal	▪ Limited TOC removal. Will likely not meet additional TOC removal requirements during portions of the year. ▪ Little T&O mitigation ▪ Limited SOC and VOC removal
Gravity Filtration with Anthracite followed by GAC Contactors	▪ GAC provides superior TOC removal ▪ GAC Contactor can be used as needed to provide the adequate level of TOC removal ▪ Superior removal of T&O causing compounds and some contaminants, ▪ Removes most SOCs and VOCs	▪ Higher capital cost for facilities ▪ GAC replacement costly, but lower than with GAC filtration media ▪ Requires additional space for contactors ▪ Some additional headloss through plant
Gravity Filtration with Anthracite preceded by Magnetic Ion Exchange (MIEX)	▪ MIEX type processes can be used intermittently or on a portion of the flow as additional TOC removal is necessary ▪ High TOC removal possible ▪ Lower coagulant chemical dose and sludge production possible	▪ Additional space required ▪ High operating cost although it could be comparable to GAC ▪ Proprietary equipment ▪ New technology with limited water industry experience ▪ Brine waste stream disposal required
Gravity Filtration with Anthracite preceded by PAC Injection	▪ PAC used only intermittently when TOC levels cannot be met through enhanced coagulation and conventional treatment ▪ Also provides good taste and odor causing compound removal ▪ Lower chemical cost than most other options ▪ PAC absorbs permanganate which helps mitigate downstream water quality problems	▪ PAC can be messy and most operators prefer not to use it. However, a properly designed bulk storage system addresses these concerns. ▪ Increased sludge production during use of PAC, as much as 20 to 40% in the annual sludge production ▪ Maintenance of basins increases with use of PAC ▪ Tall PAC silos are needed for bulk storage, which may cause community concerns ▪ TOC removal by PAC not well documented - additional testing required
Gravity Filtration with GAC Media	▪ Provides good TOC and particle removal ▪ Superior TOC removal when in biologically active filtration mode ▪ Avoids the additional cost of GAC Contactors ▪ Removes most SOCs and VOCs ▪ Superior T&O compound removal	▪ GAC's TOC removal capacity is quickly exhausted, though can still provide good T&O removal ▪ GAC media would like have to be changed out at least once every 6 months

3.6.3 Evaluation and Conclusions

Anthracite filters are very effective at particle and turbidity removal. However to achieve the necessary treatment goal of 42 percent TOC removal, an additional process would be needed, such as PAC or GAC contactors.

Magnetic Ion Exchange equipment, such as MIEX developed by Orica Watercare, is a new and emerging technology for DOC removal. There is currently one main supplier of equipment. This technology can not be recommended at this time due to the limited experience by USA water agencies. Additional information could be developed during preliminary design to further evaluate the applicability of MIEX. Because of the numerous advantages and potentially lower operating cost, bench scale testing and piloting of MIEX should be considered.

GAC contactors downstream of anthracite filters provide a number of operational benefits. This option is not recommended due to the high cost of facilities, and the lower cost options using GAC or PAC. However, GAC contactors may be reconsidered during design after development of additional information, as explained below.

To evaluate GAC and anthracite with PAC, a conceptual cost comparison was performed, see Table 3-9. This comparison was based on multiple PAC doses and GAC replacement cycles since there is limited experience or testing data available with Rio Grande water. Empty Bed Contact Time (EBCT) is a measurement for determining the amount of GAC in a filter based on the flow through the filter. Typically an EBCT between 7.5 and 15 minutes would be adequate for 10 to 15 percent TOC removal. This needs to be determined based on TOC breakthrough curves with Rio Grande water at Buckman.

Rapid Small Scale Column Testing was completed by CH2M Hill for the City of Albuquerque. The testing was completed on Rio Grande water with a 4.5 mg/L TOC concentration, slightly lower TOC than may be expected at Buckman. In the testing, an EBCT of 10 minutes was used and a carbon dose of 150 to 180 pounds of carbon per million gallons of treated water was recommended for carbon contactors designed for a staggered regeneration cycle. The evaluation included 40 percent removal of TOC by conventional jar testing (4.5 mg/L reduced to 2.7 mg/L) prior to GAC. The carbon dose selection was based upon an additional 1.2 mg/L removal of TOC by the GAC to a concentration of 1.5 mg/L in order to meet a 40 μg/L TTHM treatment goal. The Stage 2 DBPR did not actually lower the TTHM concentration to 40 μg/L, the concentration initially proposed by EPA at the time of the Albuquerque study. The study noted that 25 to 30 μg/L of TTHMs were formed per 1 mg/L of DOC. Based upon that ratio, DOC would need to be reduced to 2.0 to 2.4 mg/L to meet a TTHM goal of 60 μg/L. Because of a higher TTHM goal, the carbon dose may not be as high as the Albuquerque study indicated. The carbon dose should be evaluated through future pilot testing.

Table 3-9. GAC and PAC Cost Comparison

GAC Replacement Costs per Year	Replacement Period	Empty Bed Contact Times (EBCT)	
		7.5 min.	15 min.
	6 months	$484,840	$970,920
	1 year	$242,420	$485,460
	2 years	$121,272	$242,730
Annual PAC Cost	Plant Flow Rate During 4 Month Period	PAC Dose	
		20 mg/L	40 mg/L
	15 mgd	$163,680	$327,360
	7.5 mgd	$ 81,840	$163,680
	5 mgd	$ 54,560	$109,120

The same Albuquerque Study also evaluated the use of PAC for TOC removal. The addition of alum and PAC with submerged membranes was evaluated. A four hour contact time and a dose of 35 mg/L alum and 30 mg/L PAC was necessary to meet a TTHM goal of 40 µg/L. Testing of conventional treatment and PAC was not completed for this study. Other than the Albuquerque study, there is little data available to determine the necessary dose of PAC to remove the additional 10 to 15 percent of TOC that would be needed to meet the treatment goal. However, the general high dose range of PAC for T&O removal is typically on the order of 20 to 40 mg/L in highly organic waters. The Albuquerque study recommended a PAC dose within this range. For comparison purposes it has been assumed that an average PAC dose of 20 mg/L would be needed during the typical summer periods, and a higher dose of 40 mg/L would be used during extreme TOC periods. It appears that the additional TOC removal would be needed during the summer when the plant would likely be operating at peak flow, 15 mgd. Therefore, two scenarios were evaluated:

Scenario 1: Smaller GAC Filters vs. Low PAC Dose

- GAC Filters – 7.5 minute EBCT for GAC filters operating at 15 mgd with a replacement period of 6 months = $485,000 per year
- PAC Use – 20 mg/L dose at 15 mgd = $164,000 per year

Scenario 2: Larger GAC Filters vs. High PAC Dose

- GAC Filters – 15 minute EBCT for GAC filters operating at 15 mgd with a replacement period of once per year = $486,000 per year
- PAC Use – 40 mg/L dose at 15 mgd = $327,000 per year

These two scenarios indicate that use of PAC to meet the TOC removal requirements would save approximately $159,000 to $321,000 annually based on peak flow. It is likely that an average year would not require the additional 4 months of high TOC removal. Therefore use of PAC would likely provide an even greater cost savings over GAC filters. Another consideration is the additional sludge volume generated through the use of PAC, 380,000 to 750,000 pounds per year under the two scenarios above. This equates to an 8 percent to 16 percent increase in sludge production. However, the additional cost of sludge handling and facilities would be minimal and would not off-set the cost savings over GAC. In addition to these items there are the following considerations:

- GAC provides superior taste and odor control which would not be seen with intermittent use of PAC.
- GAC provides good SOC and VOC removal, not provided with intermittent PAC use.
- PAC use will increase maintenance requirements in basins and with sludge handling equipment.
- PAC should be fed upstream of the plant but may settle out during low velocity periods.

Therefore, based on the above comparison, it is recommended that GAC filtration be used at the MRC WTP. There are a number of variations that can be used within this option, including the following:

1. Anthracite filters with GAC caps (top layer of GAC).
2. A portion of the filters containing anthracite and others containing GAC so that a portion of settled water obtains the higher TOC removal and can be blended to meet TOC requirements.

At this time, GAC filters are recommended. To confirm this process, it is recommended that additional testing and evaluation be performed during preliminary design to develop the following:

- EBCT for GAC
- Replacement frequencies for GAC media based on TOC breakthrough
- PAC's TOC removal ability with Rio Grande water

This additional data would be used to better define the design criteria for the GAC filters and to better estimate the related costs.

It is anticipated that these filters would utilize air and water backwashing. The use of air wash minimizes the amount of backwash water used and waste washwater generated due to lower wash rates and shorter water wash durations.

In addition, it is anticipated that the backwash water would be pumped from the Clearwell Reservoir without the use of a separate backwash tank. There isn't adequate elevation difference to provide an elevated backwash storage tank. Also, the intent under the EIS is to limit taller facilities that would be visible to residents and users of the surrounding recreational areas. The design of backwashing pumping facilities needs to be incorporated into the clearwell so the hydraulics are not affected.

Filter criteria are listed in Subsection 3.12 for further consideration and evaluation during preliminary and final design.

3.7 Disinfection

3.7.1 Process Overview

Two disinfection systems are needed at the MRC WTP: a primary system for disinfection within the plant and a secondary system for disinfection within the distribution system.

As discussed in Section 2, the primary disinfection process is needed to meet CT requirements for pathogen inactivation. Based on the analysis in Section 2, the primary disinfection system must provide:

- 0.5-log *Giardia* inactivation
- 2.0-log Virus inactivation
- 1.0-log *Cryptosporidium* inactivation

In addition, secondary disinfection must provide residual disinfection for the distribution system.

3.7.2 Treatment Options

Treatment options for consideration include ozone, ultraviolet (UV) disinfection, and sodium hypochlorite. Table 3-10 provides a comparison between the various options.

Table 3-10. Disinfection Comparison

Treatment Option	Advantage	Disadvantage
Ozone	▪ Good preoxidant, strong disinfectant ▪ Highest inactivation efficiency ▪ Low DBP formation Demonstrated benefits in coagulation and filtration	▪ High capital and operating cost ▪ Requires air preparation equipment or liquid oxygen, which increases operating costs ▪ More complex maintenance and operation ▪ Production of bromate ▪ Need secondary disinfectant for residual
Sodium Hypochlorite	▪ Good disinfectant ▪ Easy operation ▪ Lowest cost ▪ Works best as a secondary disinfectant to provide chlorine residual in distribution system ▪ Only requires handling of salt ▪ Similar to equipment at other City facilities ▪ Good virus inactivation	▪ High DBP formation potential ▪ Would not meet Stage 2 DBPR requirements ▪ Not recommended as primary disinfectant due to DBP formation concerns ▪ Proprietary equipment if MIOX process used as at other City facilities
UV	▪ Demonstrated good *Giardia* and *Cryptosporidium* inactivation ▪ Easy to operate ▪ Cost effective ▪ Does not require basin, small space requirement	▪ EPA guidance manual still in draft form ▪ Will require validation testing ▪ Calgon patent may apply requiring $0.015 per 1,000 gallons payment ▪ Higher energy requirement than sodium hypochlorite

3.7.3 Evaluation and Conclusions

UV disinfection is recommended for primary disinfection since this is a lower cost alternative and easier to operate and maintain that ozonation. Sodium hypochlorite (MIOX or on-site hypochlorite generation) is recommended for a portion of primary disinfection (Virus inactivation) and for secondary disinfection. The formation of DBPs is limited with the use of sodium hypochlorite after the removal of TOC and other DBP precursors. See Subsection 3.8 for a discussion on the use of sodium hypochlorite in the Clearwell Reservoir.

It is anticipated that three UV reactors will be used at the MRC WTP, two duty and one standby. There are various types of UV reactors available for drinking water disinfection, including Low Pressure High Output (LPHO) reactors and Medium Pressure (MP) reactors. A patent payment may be required at $0.015 per 1,000 gallons. However, the final legal decisions are still pending. The cost has been included in the calculation of O&M costs at this time. Section 3.12 provides design criteria that can be used for further evaluation in the preliminary design.

3.8 Finished Water Storage

3.8.1 Overview

The finished water Clearwell Reservoir will serve numerous purposes:

- Primary disinfection of filtered water (in addition to UV on filter effluent) with sodium hypochlorite to meet CT requirements for Virus inactivation
- Addition of a secondary disinfectant (sodium hypochlorite) for distribution system residual
- Adjustment of pH and alkalinity for blending and meeting regulations
- Addition of fluoride
- Storage and pumping to the City and County distribution systems
- Pumping of water for backwashing of filters
- Pumping of water for plant water system
- Pumping of water for a NFPA rated fire protection system

3.8.2 Evaluation and Conclusions

From City staff input and the elimination of presedimentation basins, the capacity of the Clearwell Reservoir is preliminarily planned as 15 MG. This would provide approximately one day of storage at peak flow (15 mgd), and approximately three days of storage at average plant flow (5 mgd). However, the actual usable capacity of the reservoir would be 15.5 MG. The additional 0.5 MG volume would be a reserve capacity for:

- Backwashing of filters if needed upon plant startup
- Plant domestic and utility water system uses

The actual reserve capacity of the reservoir needs to be evaluated further in the preliminary design.

The Clearwell Reservoir should be designed to provide good hydraulic efficiency (greater than 0.5 T_{10}/T) to minimize the primary disinfectant dose and provide a short turnover of the water. Due to the anticipated low hydraulic grade line, and a need to meet anticipated MRC and community concerns with tall structures, an underground covered storage reservoir is anticipated in lieu of an above-ground steel storage tank. The reservoir would be well baffled for primary disinfection virtually serving as a chlorine contact basin.

As discussed in Subsection 3.7, sodium hypochlorite will be used within the Clearwell Reservoir to provide a 2.0-log Virus inactivation. Since water temperatures vary between 5 and 25 degrees C, a CT value of 4.0 to 1.0 mg-min/L, respectively, will need to be met. Therefore, a chlorine dosage of 1.2 to 2.4 mg/L will be needed in the reservoir to maintain a 0.2 mg/L residual in the reservoir to prevent biological growth even at low flow periods. To provide secondary disinfection, sodium hypochlorite will again be applied at the outlet of the reservoir. Monitoring will be provided before and after this second application of sodium hypochlorite to provide the correct dosage of chlorine to target a 0.8 mg/L residual with a minimum residual of 0.2 mg/L in the distribution systems. It is anticipated that a chlorine dose 0.8 to 1.3 will be required for secondary disinfection to achieve the desired chlorine residual in distant locations of the distribution systems.

It is recommended that a system water quality model be used to determine chlorine residuals and DBP levels in the enlarged distribution systems. Remote chlorination systems may be needed on the south side of the City and in the County.

The Clearwell Reservoir also needs to provide disinfected water for the plant water system and fire suppression system. It is anticipated that the plant, fire suppression pumps, and backwash pumps will be located near the outlet of the Clearwell Reservoir. Chlorinated water can be used for backwashing of filters since the chlorine residual has been shown to have little effect on biological activity in filter media.

3.9 Solids Handling

3.9.1 Process Overview

Solids will be generated from a number of processes within the MRC WTP. Larger solids (greater than 0.1-mm to 0.3 mm) will be removed near the Buckman Diversion structure. Waste streams will be generated from the following processes at the MRC WTP:

- Sedimentation basins during blowdown
- Filters after backwashing (termed waste washwater)
- Filters when being placed back in operation (filter-to-waste)
- Process basin drains

As discussed earlier, approximately 4.8 million pounds of sludge (as dry solids) will be produced annually. Unfortunately, there is considerable uncertainty in the volume calculation because the suspended solids loading in the river is unpredictable per CH2MHill. This estimated volume is believed to be slightly conservative. Without proper planning and design, the handling of solids at the MRC WTP could easily be the rate limiting process.

3.9.2 Treatment Options

Numerous treatment options are available for handling and dewatering solids at the MRC WTP. Table 3-11 provides a comparison between the more viable alternatives.

Table 3-11. Solids Handling and Dewatering Options Comparison

Option	Advantage	Disadvantage
Discharge to Sanitary Sewer	▪ Low maintenance for WTP ▪ Requires little space ▪ Minimal water lose due to evaporation	▪ High cost due to the need for miles of pipelines and possible booster pump stations ▪ Additional solids loading, and related cost, for wastewater facility to treat ▪ No reclaimed water recycle ▪ Numerous permits and ROWs would likely be needed
Equalize-Dry in Lagoons-Send to Landfill	▪ Simplest process ▪ Low capital cost ▪ Provides good drying of solids (>50% depending when solids are removed from lagoons)	▪ Without intermittent thickening, numerous lagoons would be needed ▪ Higher maintenance with numerous lagoons ▪ High evaporative loses with numerous lagoons ▪ Disposal fees for landfill
Equalize-Thicken-Dry in Lagoons-Send to Landfill	▪ Relatively simple process ▪ Moderate capital cost and O&M cost ▪ Provides good drying of solids (>50% depending when solids are removed from lagoons)	▪ Thickeners require attention ▪ Ferric chloride sludge will be moderately corrosive ▪ Relatively high maintenance ▪ Disposal fees for landfill
Equalize-Thicken-Storage-Dewater with Filter Press-Send to Landfill	▪ Lowest space requirement ▪ Provides good drying of solids (30% to 45%)	▪ High capital and operating cost ▪ Filter presses (belt, plate and frame, etc.) can be problematic ▪ Additional pumps and equipment creating high maintenance ▪ Disposal fees for landfill slightly higher than with lagoon drying

There are also numerous alternatives under each treatment option. For example, thickening can be provided through the use of gravity thickeners, Claricone, centrifuges, vacuum filters, or other manufacturer's equipment. Also, waste washwater can be combined with sedimentation blowdown or kept segregated. Filter presses and lagoons could both be used to provide redundancy. Filter-to-waste water can be directly equalized and pumped, or stored and pumped, directly to the plant influent prior to coagulation.

3.9.3 Evaluation and Conclusions

All the options in Table 3-11 are viable options that should be considered as this project moves through preliminary and final design. In order to provide a workable process that is conservative in space requirements the Equalize-Thickener-Lagoons-Landfill option has been selected with the addition of a filter press for multiple system redundancy in cost estimating.

<u>Sedimentation Blowdown</u> At 1 to 2 percent solids, the intermittent flow would be conveyed to a equalization basin to provide a downstream gravity thickener(s) with a constant influent flow. The gravity thickener(s) could produce up to 5 percent solids with the addition of a polymer or coagulant. The thickened sludge would then be pumped, or possible flow by gravity, to lagoons for drying up to 60 percent solids, or more, depending when the material is removed.

<u>Waste Washwater</u> The filter waste washwater would flow to from the filters to an equalization basin. A lower constant flow rate would then be conveyed to gravity thickeners where polymer would be added to promote solids settling. At 2 to 3 percent solids, the thickened flow would be conveyed to the lagoons where settling, decanting and drying would occur.

<u>Filter-to-Waste</u> This relatively clean waste stream would flow from the filters to a holding basin and pump station.

It is currently envisioned that the solids handling facilities would consist of the following:

- Individual equalization basins for the segregated sedimentation basin blowdown and filter waste washwater, one basin per flow stream. The basins would need to be designed so solids are flushed to the outlet.
- Equalization basins allow the downstream thickeners to treat a smaller constant flow.
- Three gravity thickeners for individually treating sedimentation basin blowdown and filter waste washwater. The third gravity thickener could be used as a standby or alternate between treating the two streams.
- Gravity thickeners increase the settleability of solids and reduce loading onto the lagoons by more than 50 percent. Decant from the thickeners would flow to the lagoon decant pump station holding basin.
- Six drying lagoons would be used for treating thickened solids from the gravity thickeners.
- An estimated 1.6 million pounds of dry solids would be treated in the lagoons annually. (UPDATE MASS?) With three drying periods and a fourth resting period during the winter months, the lagoons would be cycled through a cycle of flow through and decant – drying – sludge removal.
- Sludge removal from the lagoons would be a fairly constant operation using a front-end loader and dump truck. The dried material would be trucked to the local landfill for disposal.

- Decanted water from the gravity thickeners and lagoons would be contained in a holding basin. This would allow vertical turbine pumping to the water treatment basins prior to coagulation. Pumping back to the process basins at a lower constant flow minimizes water quality impacts to the process.

All of the solids handling facilities need to be designed to provide flexibility, redundancy and robust treatment of waste streams to minimize O&M costs and to ensure that the water treatment process is not limited by the plant's solids handling capacity. As with all other plant facilities, the solids handling facilities must be capable of handling the wide variation in water quality that will impact the volume of solids generated during different seasons of the year. Therefore, to provide additional solids handling capacity for extreme periods, a high-rate sludge handling process, such as a belt-filter press, is recommended.

3.10 Chemical Storage and Feed Facilities

3.10.1 Overview

Chemical addition at the MRC WTP is necessary to provide good solids and TOC removal, removal and inactivation of pathogens, removal of contaminants, condition water for blending, and regulatory compliance. There are numerous options for storing and feeding chemicals to the various processes.

3.10.2 System Options

Table 3-12 provides a comparison of the various chemical storage and feed options for the MRC WTP.

Table 3-12. Chemical Storage and Feed Options

Option	Advantage	Disadvantage
Storage Alternatives		
Bulk Storage Tanks	▪ Number of compatible materials ▪ Can provide good positive head for metering pumps ▪ Can allow adequate storage volume of liquid chemicals	▪ Requires inspection and periodic maintenance to avoid leaks ▪ Requires secondary containment of hazardous chemicals
Totes and Drums	▪ Good storage of liquid chemicals where low feed rates are used	▪ Requires handling and use of forklift, overhead crane and/or pallet dolly
Silos for Dry Chemicals	▪ Good storage for feeding volumetric or gravimetric feeders ▪ Necessary with certain types of chemicals such as PAC	▪ Tall silos do not meet anticipated concerns with MRC and surrounding community ▪ City prefers use of liquid chemicals
Gaseous Chemicals in Cylinders or Tanks	▪ Horizontal tanks compatible with anticipated site concerns ▪ Necessary storage container for gaseous chemicals such as chlorine ▪ Would be needed for liquid oxygen storage should ozone be used	▪ Typically required to be stored outside of structures ▪ Typically used for highly hazardous chemicals such as anhydrous ammonia ▪ City prefers use of liquid chemicals

Table 3-12. Chemical Storage and Feed Options

Option	Advantage	Disadvantage
Chemical Feed		
Metering Pumps	▪ Provides accurate metering of liquid chemicals over a wide range of feed rates ▪ Similar to equipment used by City at Canyon Road WTP	▪ Good design details needed to provide positive head to pumps and other features ▪ Typical equipment maintenance required including daily calibration and inspection
Pressurized System with Flow Metering and Control Valves	▪ No metering pumps involved ▪ Uses centrifugal pumps to pressurize looped piping	▪ Numerous meters and control valves needed to provide a wide range of feed rates ▪ Requires calibration of meters ▪ Pressurized pipe more susceptible to leakage
Volumetric or Gravimetric Feeders	▪ Good feed method for dry chemicals	▪ City prefers use of liquid chemicals ▪ Requires additional maintenance

3.10.3 Evaluation and Conclusions

Based on the City's current use of equipment at the Canyon Road WTP and other facilities and preferences provided as input for this project, the following types of equipment are recommended for supplying and feeding of chemicals at the MRC WTP:

- Bulk storage tanks should be used for storage of liquid chemicals to provide 30 days of storage at average flow and average dose. Where the stored volume would be greater, tanks should be designed for 14 days of storage at maximum dose and maximum plant flow.
- Bulk storage tanks should be designed with industry standard materials that provide good chemical compatibility.
- Bulk storage tanks should be provided with secondary containment, monitoring (such as liquid levels), drain valves and piping for flushing, adequate access for maintenance, and other regulated and industry standards.
- Where necessary, totes and drums should be used to provide storage of chemicals that have low feed rates, such as polymers.
- Systems using drums or totes should be designed to provide easy handling and connection to feed systems.
- Dry salt storage will be needed for the plant's sodium hypochlorite (MIOX) system which the City prefers to use.
- Liquid chemicals should be metered and fed through the use of positive displacement type metering pumps (mechanical and/or tubular diaphragm type).
- Metering pumps should be provided with adequate positive suction head, safety features (such as pressure relief), control features (electronic speed and stroke control) and other industry standards and City preferences.

- Polymers should be metered and feed with polymer blending units that include metering pumps.
- Sodium hypochlorite should be generated and feed using a salt based feed system such as MIOX.

In addition to these recommendations, it will be important to work with the City's staff through the preliminary design process on specific details of the chemical facilities to provide systems tailored to City's operations and maintenance needs.

Table 3-13 provides a listing of the anticipated chemicals developed through the water quality testing and evaluations provided in this Report. The table also lists the primary and secondary feed points. Primary points of applications are the points within the treatment process where the chemicals would normally be fed. Secondary points of application are the points where the chemicals could be fed to aid in startup, maintenance, or addressing special or changing water quality concerns.

Table 3-13. Recommended Chemicals and Feed Locations

Chemical and Use	Primary Application	Secondary Application
Sodium Permanganate: Preoxidation, algae control, iron and manganese removal, taste and odor control, enhance coagulation	▪ Booster Station 2A or upstream of the plant to provide long contact time	▪ Just prior to first stage of rapid mixing if primary point can not be accommodated
Ferric Chloride and Polyaluminum Chloride: Primary coagulants for particle and TOC removal	▪ First stage of rapid mix to combined plant flow containing recycled flow	▪ Second stages of rapid mix, at head of each process train, in case first stage mixing is shutdown
Coagulant Aid Polymer: Cationic polymer to aid in coagulation for particle and TOC removal	▪ Second stages of rapid mix at the head of each process train ▪ Backwash water prior to filters for last stage of backwash for ripening of media	▪ None
Flocculant Aid Polymer: Nonionic polymer to provide heavier, large and tougher floc for removal in sedimentation basins and filters	▪ Second stage of flocculation basins	▪ None
Filter Aid Polymer: To provide enhanced particle removal in filter media	▪ Applied water channel	▪ None
Sodium Hypochlorite: To provide pathogen inaction, prevent bacterial and slim growth, and secondary disinfection and residual for the distribution systems	▪ Inlet of Clearwell Reservoir for additional primary disinfection ▪ Outlet of Clearwell Reservoir for secondary disinfection	▪ Second stage of rapid mix for periodic process basin disinfection ▪ Filter applied water for startup disinfection and periodic cleaning of filters
Sodium Hydroxide: For raising pH of finished water and addition of some alkalinity	▪ Intermediate section of Clearwell Reservoir	▪ None
Hydrofluosilicic Acid: Fluoridation of drinking water	▪ Inlet of Clearwell Reservoir	▪ None
Thickening Polymer: To aid in settling and thickening of waste washwater and sedimentation blowdown in gravity thickeners	▪ Inlet mixing zone of gravity thickeners	▪ None

Table 3-13. Recommended Chemicals and Feed Locations

Chemical and Use	Primary Application	Secondary Application
Spare Chemical System: Allows chemical addition for trial chemicals or chemicals needed to address periodic needs. Possibly corrosion inhibitor or pH suppressant.	▪ First stage of rapid mix ▪ Second stages of rapid mix ▪ Clearwell Reservoir inlet ▪ Clearwell Reservoir outlet	▪ NA

3.11 Support Facilities

3.11.1 Overview

The non-process facilities, or support facilities, are extremely important in meeting treatment goals. These are the facilities that enable the City's staff to efficiently operate and maintain the treatment facilities.

3.11.2 Evaluation and Conclusions

The support facilities, their goals, and the approximate number or size, are shown in Table 3-14. The information included in the table has been based on discussions with the City and PNM, and through other sources.

Table 3-14. Recommended Support Facilities

Facility	Purpose/Goals	Criteria
Administration Building	▪ Allows the staff to work in an efficient manner ▪ Good monitoring of traffic and people in and out of facilities ▪ Provides good monitoring and control of WTP process equipment and supply facilities	▪ Approximately 5,000 square feet with laboratory and maintenance facilities ▪ Six offices, break room, locker rooms, supply closet, conference/training room ▪ Receptionist area
Electric Power Facilities	▪ Minimizes downtime due to electrical supply or distribution problems ▪ Allows for safe and effective operation and maintenance of the facilities	▪ Transformer(s) ▪ Power distribution panels
Laboratory Facilities	▪ Allows monitoring of processes ▪ Provides equipment necessary for evaluation of processes and reporting ▪ Basic water treatment sampling and analysis, some outside laboratory analysis will be needed	▪ Minimum 25' x 25' area ▪ Supplies storage ▪ Equipment for process sampling and testing ▪
Maintenance Facilities	▪ Provides for good maintenance of plant equipment ▪ Minimizes downtime of treatment equipment	▪ Minimum 40' x 40' area ▪ Four work areas within maintenance facility ▪ Parts storage area
Site Security Facilities	▪ Provide staff safety ▪ Prevent tampering with public water supply	▪ Security gate with intercom and key codes ▪ Perimeter security such as surveillance cameras ▪
Standby Power Facilities	▪ Allow distribution of water from Clearwell Reservoir at all times ▪ NFPA rated fire suppression system	▪ Designed to meet codes for NFPA fire protection ▪ Sized to meet peak flow demands

3.12 Summary of Recommended Processes

3.12.1 Process Overview

As discussed and evaluated in Sections 2 and 3, the selected treatment train consists of the following processes to meet treatment goals. These processes, shown in Figures 3-1, 3-2 and 3-3, will be evaluated and refined during the preliminary design of the project facilities.

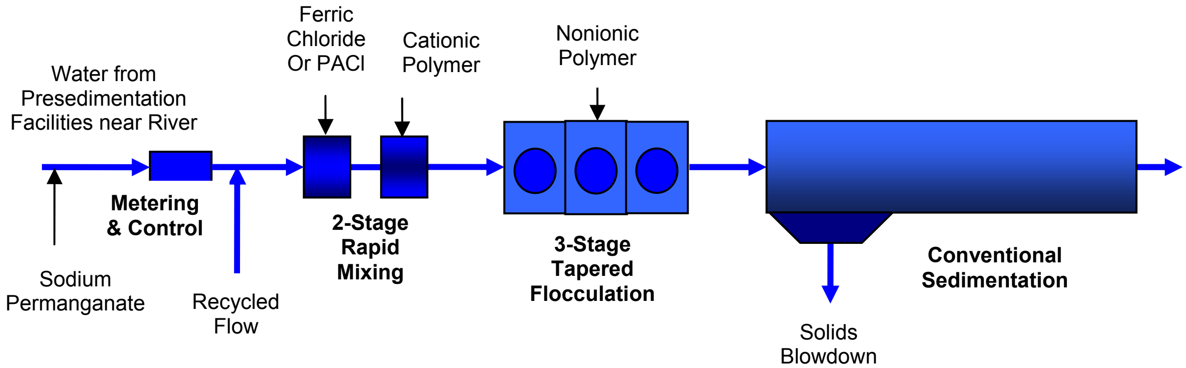


Figure 3-1. Coagulation, Flocculation and Sedimentation Processes

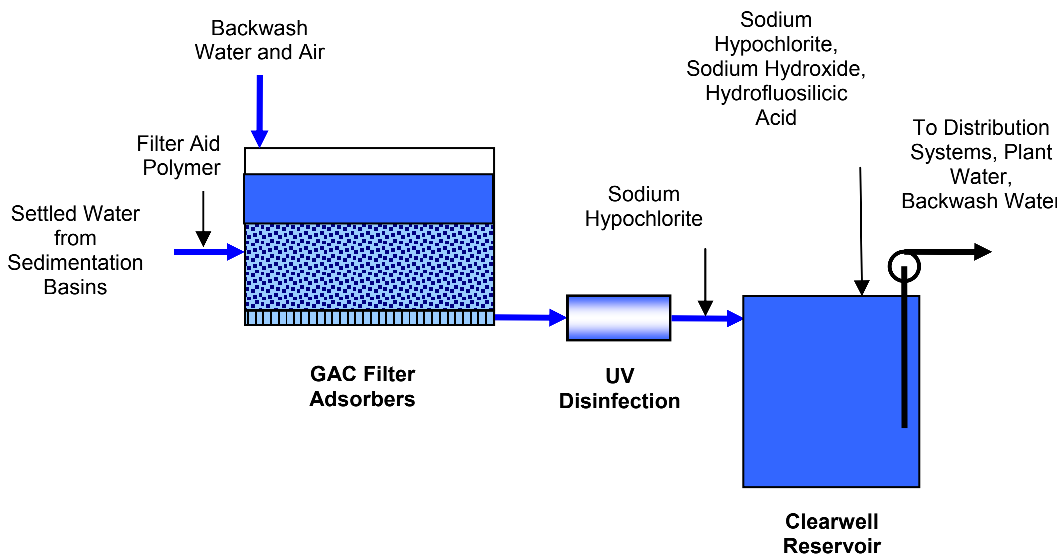


Figure 3-2. Filtration, UV and Storage Processes

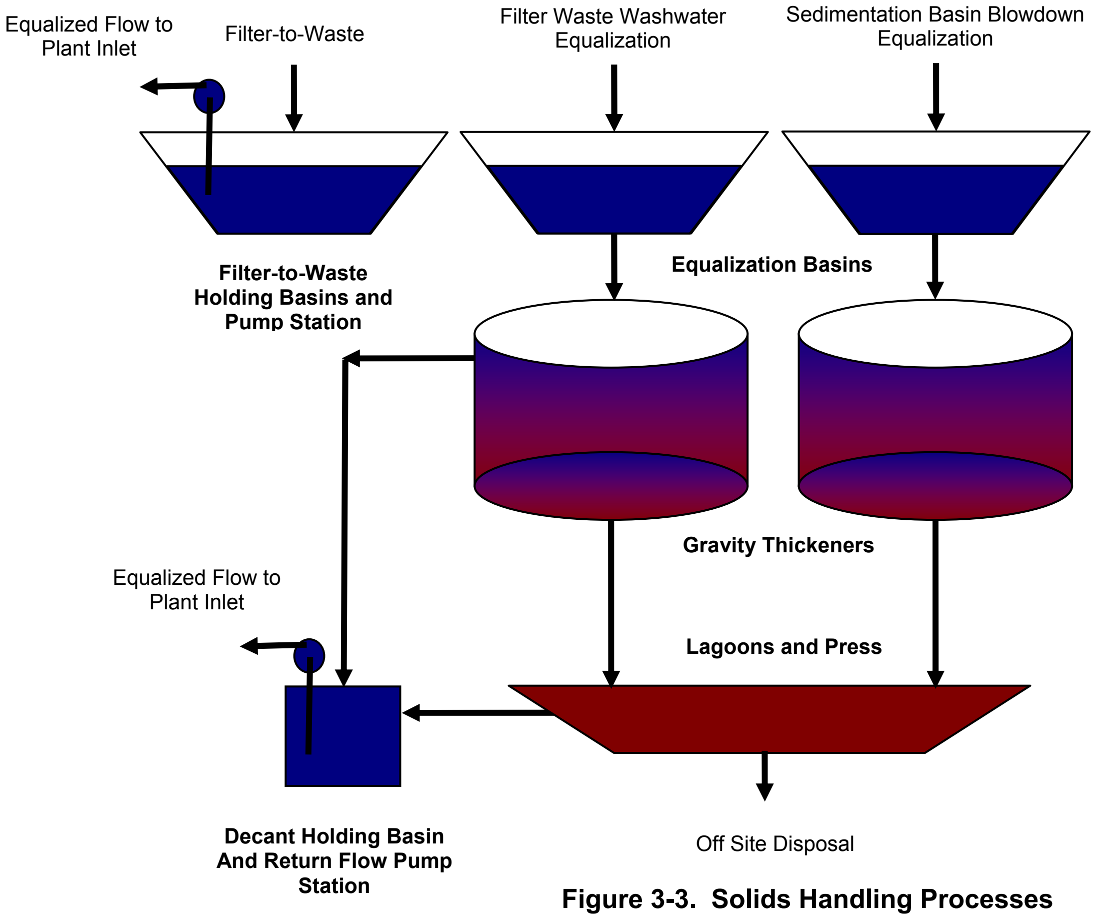


Figure 3-3. Solids Handling Processes

Presedimentation – No facilities are anticipated at the MRC WTP. Solids greater than 0.1-mm to 0.3-mm will be removed at the diversion facilities which are not addressed in this Report. A surge tank is likely needed at the inlet to the MRC WTP as part of the booster system.

Preoxidation – Sodium permanganate will be used as a pre-oxidant for iron and manganese removal, taste and odor causing compound control, algae control, and enhancement of coagulation. It is recommended that this liquid chemical be fed at Booster Station 2A to provide adequate contact time prior to coagulation and flocculation.

Coagulation – A two-stage rapid mix process will be used for injection of the primary coagulant and a coagulant aid polymer. The primary coagulant, either ferric chloride or polyaluminum chloride, will be injected at the first stage of rapid mixing of the entire plant flow. The flow will then be divided into three process trains with the second stage of mixing at the head end of the flocculation basins. A counter-current jet type mixer is envisioned for both stages of mixing.

Flocculation – Three treatment trains, each with three stages of flocculation will be used to create a settable floc. Horizontal paddle wheel flocculators with variable frequency drives will provide good tapered flocculation. The flocculant aid polymer will help create a tough heavy floc.

Sedimentation – Three long rectangular sedimentation basins will provide good removal of settable floc. Sludge will be pushed to sludge hoppers at the front end of the basins with either chain and flight collectors, or newer systems such as a SuperScraper. Sludge will be withdrawn from the hoppers using telescoping valves.

Filtration – Six GAC filter adsorbers will provide turbidity and particle removal, additional TOC removal, SOC and VOC removal, and taste and odor causing compounds removal. Four filters will provide the peak treatment flow (at 6 gpm/sf) with one additional filter in backwash mode and another filter in standby or maintenance mode. A filter aid polymer will be added to the settled water prior to the filters. Backwash water and air will be provided through an underdrain system for particle removal of the media. Filter-to-waste will be used to remove the slightly high turbidity in the filtered water after a filter is put back into operation after a backwash. The backwash water will be provided through pumps at the Clearwell Reservoir.

Ultraviolet Disinfection – Additional treatment goals, *Cryptosporidium* and *Giardia* inactivation will be provided by two UV reactors. A third UV reactor will be used in a standby module.

Clearwell Reservoir – A 15 million gallon (nominal) reservoir will be used to supply the City and County connections. An additional 0.5 million gallons will be stored in the reservoir for the plant's use: fire protection, plant water and backwash water. Sodium hypochlorite will be introduced at the beginning of the reservoir for Virus inactivation. Sodium hypochlorite will be introduced again, after monitoring, to provide a disinfection residual in the distribution systems. Booster Stations 4A and 5A will be located at the Clearwell Reservoir for distributing treated water to the City and County.

Solids Handling – Equalization basins, gravity thickeners, and a belt filter press will be used to treat the solids streams from the sedimentation basins and the filters. Sludge lagoons are also proposed to provide system redundancy to handle the potentially 20 times volume change in solids at certain times of the year. Decant from the thickeners, lagoons, and press will be pumped back to the head of the treatment plant. Dried sludge will be removed from the lagoons or press and disposed of at the Caja del Rio landfill. Filter-to-waste will be equalized and pumped back to the head of the treatment plant.

3.12.2 Plant Criteria

Table 3-15 provides plant criteria for the cost estimating and layout of the facilities. The criteria should be used in developing the preliminary design.

Table 3-15. Preliminary Plant Criteria

Characteristic	Unit	Criteria
Plant Capacity	mgd	15
- Process Trains	no.	3
- Design Capacity per Train	mgd	5
- Average Plant Flow Rate	mgd	6.2
Rapid Mixing		
- Mixer Type	–	Counter Current Jet Mixing
- No. of Stages	no.	2
- 1st Stage Units	no.	1 at 400 gpm
- Mixing Energy, G at 10 °C and 15 mgd	sec -1	1000
- 2nd Stage Units	no.	3 at 150 gpm
- Mixing Energy, G at 10 °C and 5 mgd	sec -1	800
Flocculation		
- Mixer Type	–	Horizontal Paddle Wheel
- Drive Motor	–	Variable Frequency Drive
- No. of Basins	no.	3
- Detention Time (15 mgd)	min	15
- Stages per Basin	no.	3, Separated by Baffle Walls
- Basin Depth	ft	17
- Water Depth	ft	15
- Basin Volume	gal	52,080
- Basin Dimensions (rectangular)	LxW, ft	36' x 13'
- Mixing Intensity, G (Stages 1, 2, 3) at 10 °C and 15 mgd	sec -1	40 to 80, 40 to 60, 10 to 40
- No. of Flocculators	no.	9, 3 per Process Train
- Mixer HP	hp	5
- Maximum Tip Speed	fps	2
- Total Paddle Area per Stage	sf	95
Sedimentation		
- Type	–	Horizontal flow
- No. of Basins	no.	3, 1 per Process Train
- Detention Time (15 mgd)	min	90
- Surface Loading Rate, Effective (15 mgd)	gpm/sf	0.5
- Basin Depth	ft	12
- Water Depth	ft	8
- Overall Basin Dimensions	LxW, ft	204 x 34
Sludge Collection and Removal		
- Sedimentation Basin Collector Type	–	Scraper type System
- Collectors per Sedimentation Basin	no.	1
- Air Compressor to Operate Each Collector	hp	5
- Sludge Concentration in Sedimentation Basin	%	1
- Mass Dry Solids in Sed Basin (ave. flow/ave. FeCl3 dose)	lb/day	13,200
- Mass Dry Solids in Sed Basin (max. flow/ave. FeCl3 dose)	lb/day	31,900
- Volume Sludge from Sed Basin (ave. flow)	gal/day	1,600
- Volume Sludge from Sed Basin (max. flow)	gal/day	3,800
- Backwash Water Volume per Day (2 filters per day)	gal/day	386,300

Table 3-15. Preliminary Plant Criteria

Characteristic	Unit	Criteria
Filters		
- Type	–	Gravity, Constant Rate (Flow Controllers)
- No. of Filters	no.	6
- No. of Bays per Filter	no.	1
- Filter dimensions	LxW, ft	12 x 36
- Media Surface Area (each filter)	sf	432
- Media Surface Area (total)	sf	3,456
- Filtration Rate (15 mgd)		
- All Filters Online	gpm/sf	4.0
- One Filter Offline	gpm/sf	4.8
- Two Filters Offline	gpm/sf	6.0
- Empty Bed Contact Time (EBCT)	min	7.5 with 4 Filters
- Key Filter Component Elevations (ft above filter bottom)		
- Top of Media	ft	6
- Top of Wall	ft	18
- Maximum Water Surface	ft	14
Filter Media		
- GAC		
- Depth	in	72
- Effective Size, d10	mm	1.4
- Uniformity Coefficient, d60/d10	–	1.25
- Specific Gravity	–	1.35
- L/D ratio	mm/mm	907
Filter Backwash		
- Backwash Type	–	Backwash w/Air Scour
- Underdrain Type	–	Nozzle
- Backwash Water Supply		
- Type	–	Vertical Turbine
- Number	–	3
- Capacity	gpm	4,000/8,000 (2)
- Power	hp	60/125 (at 50 ft TDH)
- Air Scour Air Supply		
- Type	–	Centrifugal Blower
- Number	–	2
- Capacity	scfm	2,400 scfm
- Power	hp	200 at 16 psi
- Backwash Rate per Filter (air only/both/water only)	gpm/sf	0/4.4/15
- Backwash Flow per Filter (air only/both/water only)	gpm	0/3,441/11,730
- Backwash Duration per Filter (air only/both/water only)	min	0/5/15
- Backwash Volume per Filter	gal	193,150
- Air Scour Rate per Filter (air only/both/water only)	scfm/sf	3/3/00
- Air Scour Flow per Filter (air only/both/water only)	scfm	2,346/2,346/0
- Air Scour Duration per Filter (air only/both/water only)	min	5/5/00
- Air Scour Volume per Filter	scf	23,460
- Media Expansion (at High Flow Water Alone)	%	25
UV Disinfection		
- -Type	–	Closed Reactor. Medium Pressure
- Location	–	End of Filters
- Number of Reactors	no.	3, 2 duty and 1 standby
- Capacity of Each Reactor	MGD	7.5
- UV Dose	MJ/cm^2	40

Table 3-15. Preliminary Plant Criteria

Characteristic	Unit	Criteria
Clearwell		
- Type	–	Rectangular, Buried Concrete
- Number of Cells	no.	4
- Capacity (each cell)	MG	4
- Total Capacity	MG	15.5
- Dimension	ft x ft	200 x 350
- Water Depth (maximum)	ft	30
- Number of Baffles	no.	4
Coagulant Storage/Feed System		
- Coagulant Compatibility	–	Ferric Chloride and PACl
- Application Point	–	Rapid Mix Stage 1
- Chemical Form	–	Liquid Solution
- Neat Solution Strength	%	38% ($FeCl_3$)
- Average Dose	mg/L	21 ($FeCl_3$)
- Feeder Type	–	Chemical Metering Pump
- Number of Feeder Units	no.	3
- Storage Tank Material	–	Bulk Tank, XLPE
- Number of Storage Tanks	no.	2
- Total Storage Capacity	gal	15,000
- Storage (average flow/average dose)	days	71
Sulfuric Acid Storage/Feed System		
- Application Point	–	Rapid Mix Stage 1
- Chemical Form	–	Liquid Solution
- Neat Solution Strength	%	93% H_2SO_4
- Average Dose	mg/L	10
- Feeder Type	–	Metering Pumps
- Number of Feeder Units	no.	2
- Storage Tank Material	–	Steel
- Number of Storage Tanks	no.	1
- Total Storage Capacity	gal	3,000
- Storage (average flow/average dose)	days	82
Caustic Soda Storage/Feed System		
- Application Point	–	Finished Water Clearwell
- Chemical Form	–	Liquid Solution
- Neat Solution Strength	%	50% (6.38 lb dry NaOH/gal)
- Average Dose	mg/L	11
- Feeder Type	–	Metering Pumps
- Number of Feeder Units	no.	2
- Storage Tank Material	–	Bulk Tank, XLPE
- Number of Storage Tanks	no.	1
- Total Storage Capacity	gal	15,000
- Storage (average flow/average dose)	days	82
Sodium Hypochlorite Storage/Feed System		
- Application Point	–	1-Clearwell Influent 2-Clearwell Outlet
- Average Dose	mg/L	2.4
- Feeder Type	–	Metering Pumps
- Number of Feeder Units	no.	2
- Storage Tank Type/Material	–	MIOX
- Number of Generators	no.	4, 3 duty and 1 standby
- Total Storage Capacity	gal	10,000
- Storage (max. flow/average dose)	days	1

Table 3-15. Preliminary Plant Criteria

Characteristic	Unit	Criteria
Cationic Polymer Storage/Feed System		
- Application Point	–	1-Rapid Mix, Second Stage
- Neat Solution Strength	%	100, Assumed
- Average Dose	mg/L	1
- Feeder Type	–	Continuous Flow Polymer System (Hydraulic Mixing)
- Number of Feeder Units	no.	1
- Storage Tank Type/Material	–	Portable, 150 gal each
- Number of Containers	no.	6
- Total Storage Capacity	gal	900
- Storage (max. flow/average dose)	days	63
NonIonic Polymer Storage/Feed System		
- Application Point	–	Flocculation, 2nd Stage
- Neat Solution Strength	%	100, Assumed
- Average Dose	mg/L	0.5 (floc aid), 0.005 (filter aid)
- Feeder Type	–	Continuous Flow Polymer System (Mechanical Mixing)
- Number of Feeder Units	no.	2
- Storage Tank Type/Material	–	55-gal Drums
- Number of Containers	no.	8
- Total Storage Capacity	gal	440
- Storage (max. flow/average dose)	days	63
Hydrofluosilicic Acid Storage/Feed System		
- Application Point	–	Clearwell Outlet
- Neat Solution Strength	%	17
- Average Dose	mg/L	1
- Feeder Type	–	Chemical Metering Pump
- Number of Feeder Units	no.	1
- Storage Tank Type/Material	–	Bulk Tank/XLPE
- Number of Storage Tanks	no.	1
- Total Storage Capacity	gal	6,000
- Storage (max. flow/average dose)	days	85
Spare Chemical Storage/Feed System		
- Application Point	–	Rapid mix, settled water and clearwell
- Neat Solution Strength	%	TBD
- Average Dose	mg/L	TBD
- Feeder Type	–	Metering Pumps
- Number of Feeder Units	no.	3
- Storage Tank Type/Material	–	Bulk Tank/XLPE
- Number of Storage Tanks	no.	1
- Total Storage Capacity	gal	15,000

Section 4
Cost Estimates

4.1 Construction Costs

A construction cost estimate was prepared for the plant based upon the selected process options discussed in Section 3 and summarized in Subsection 3.12. The cost estimate was performed using cost estimating software for the Santa Fe, New Mexico area. Material volumes were based upon the anticipated unit process size. Lump sum costs of individual items, such as metering pumps, are based upon experience in preparation of water treatment plant cost estimates. The following assumptions were made in preparation of the construction cost estimate:

- Fencing will be PVC coated (colored, non-reflective), 8-ft high, with razor wire.
- Landscaping will consist of native vegetation seeding and 50 piñon trees, and includes an allowance for temporary irrigation.
- Entrance roadway and roadways within the plant site will be asphalt surfaced.
- Site lighting, security system, entrance gate, and facility sign required.
- Administration building 5,000 square feet in size with laboratory, maintenance area, offices, break room, and control room.
- Enclosed process basin area
- One standby pump provided for all chemical feed metering pumps, finished water pump stations, filter to waste system, lagoon decant recycle and MIOX system.
- One spare chemical feed system and space for a second spare chemical feed system included within chemical building.
- Administration building and chemical storage and feed area sprinklered and include HVAC systems.
- Overhead crane system included for chemical feed area.
- Drying lagoons lined with gunite and gravel
- New heavy equipment required including two solids handling trucks and forklift.
- Plant personnel trucks not included in costs.
- Emergency generator and NFPA fire pump necessary. Power supplied from new PNM substation located south of the WTP site adjacent to Caja del Rio Road.
- SCADA system and significant process instrumentation and control included

- Construction costs for the diversion and transmission facilities not included in this estimate.
- Inflation of 3.5 to adjust January 2004 draft estimate to January 2005 dollars added to previous item subtotals

The additional provisions were added to the construction cost subtotal:

- Field Office Overhead – 10%
- Contingency – 20%
- Contractor Overhead and Profit – 15%
- Insurance and Bonds – 2.5%
- Change Order Allowance – 3%
- Material Escalation of 10 percent to account for higher steel and other material costs
- New Mexico Gross Receipts Tax – 7.5625%

The construction cost estimate and additional provisions are summarized in Table 4-1. The detailed construction cost estimate is included at the back of Section 4.

Table 4-1. Summary of Construction Costs

Description	Estimated Cost
Site Work	$752,700
Administration Building	$1,239,600
Process Basins	$10,911,100
Clearwell Reservoir	$8,735,400
Solids Facilities	$4,005,100
Drying Lagoons	$1,602,000
Chemical Facilities	$2,747,700
Miscellaneous Work Items	$2,411,600
Subtotal	**$32,405,200**
Material Escalation	$3,240,500
Contingencies	$7,100,000
Profit, Overhead, Insurance, Bonds	$11,900,000
Change Order Allowance	$1,650,000
NMGRT	$4,250,000
Construction Total	**$60,545,700**

The total construction cost is estimated at approximately $60.5 million (January 2005 dollars). This estimate is about 61 percent more than the previous estimate of $37.5 million presented in the CDM report entitled *Feasibility Study and Recommendations for San Juan-Chama Water Diversion*, September 2002. The main causes for the escalated costs are as follows: larger clearwell, material escalation for steel prices, additional sludge facility, MIEX facility, inflation, and the inclusion of 7.5625 percent NMGRT.

The cost of $60.5 million is a construction cost. For a total project cost, which is outside the scope of this study, additional costs and markups are required for the capital cost of the project, such as City administration, engineering, etc. Additional construction costs are needed for the diversion intake facilities, the booster stations and pipelines, the distribution system connections, and other facilities.

As discussed previously, the facilities developed within this Report are to be further refined during the preliminary design. It is anticipated that cost saving measures may be used for further reduce the construction cost. For example, the process basins are completely enclosed. Some treatment plants in similar climates allow the flocculation and sedimentation facilities to remain uncovered.

4.2 Operation & Maintenance Costs

Estimation of operation and maintenance costs (O&M) are necessary for planning and budgeting for the new facility. The costs to operate and maintain the new MRC WTP will result in a significant increase in the overall water division budget.

Numerous assumptions were made in preparation of the O&M estimate. The assumptions are outlined in the following bullets:

- The facility will operate on two, 12-hour shifts. Two sets of operations and maintenance staff are necessary to cover all shifts during the week.
- Normal day shift staff will include the plant superintendent, a plant operator (grade IV), administrative assistant, one quarter-time safety/compliance officer, two junior operators, one junior operator dedicated to solids handling, a laboratory technician, two maintenance personnel, and an instrument technician.
- Some staff will work 8-hour shifts and position will be covered by only one employee: administrative assistance, safety/compliance officer, solids handling operator and instrument technician.
- Normal night shift staff will include a plant operator and a junior operator.
- Salaries with fringe benefits based upon information provided by Gary Martinez.
- All operating costs based upon an average plant flow of 6.2-mgd, or the total City/County SJC planned water right of 6,930 AFY divided by 365 days of operation.
- Chemical costs based upon average dose determined from bench-scale testing, equilibrium modeling, or experience.
- Quotations from chemical suppliers were obtained for all chemicals.
- Materials and supplies costs provided for office supplies, uniforms, training, laboratory fees, repair and maintenance material for the WTP, operation and maintenance of heavy equipment and miscellaneous costs.

- Provision for payment of the \$0.015/1,000 gallon Calgon UV patent included in materials and supplies costs.
- Replacement of GAC includes delivery of new GAC and hauling away of spent GAC.
- Equipment horsepower and percent time in operation estimated and used for estimating electrical usage.
- Electrical cost of \$0.07/kwh assumed from existing service agreements with PNM.
- O&M costs for Distribution Booster Stations 4A and 5A not included.
- Solids disposal costs assume disposal at the nearby Caja del Rio Landfill and are based upon a \$26.25 plus tax per wet ton tipping fee, a 4-mile round trip haul length, and laboratory analytical testing for each load.

Table 4-2 presents a summary of the estimated O&M costs. These costs are in 2004 dollars. The detailed O&M estimate is included at the end of Section 4.

Table 4-2. Summary of Operation and Maintenance Costs

Description	Estimated Cost
Labor	\$1,176,000
Chemicals	\$149,000
Materials and Supplies	\$974,000
Electric	\$500,000
Waste Solids Treatment and Disposal	\$167,000
Total Annual Cost	**\$2,966,000**
Total Cost per 1,000 Gallons	**\$1.31**

The relatively high treatment cost (greater than \$1.25 per 1,000 gallons) can be attributed to:

- Handling and treatment of approximately 4.8 million pounds of dry solids per year.
- Use of high doses of primary coagulants and GAC filter adsorbers for removal of TOC.
- GAC replacement frequency of 6 months on each of the six filters.

As previously noted, limited enhanced coagulation studies and GAC column testing or piloting have been performed with Rio Grande water. The doses and GAC replacement frequency assumed in these costs are conservative.

MRC Water Treatment
Annual Operations and Maintenance Cost Estimate
Summary

ANNUAL O&M COST SUMMARY		
Average Yearly Flow Rate (mgd)		6.2
Item		
1	Personnel	
	Day Shift	$939,000
	Night Shift	$237,000
	Subtotal	$1,176,000
2	Chemicals	
	Cationic Polymer (8105)	$14,000
	Ferric Chloride	$22,000
	Filter Aid Polymer	$8,000
	Hydrofluosilicic Acid (23% Liq Soln)	$3,000
	Nonionic Polymer (8181)	$15,000
	Polyaluminum Chloride (PAX-18)	$12,000
	Salt (for MIOX)	$17,000
	Caustic Soda	$13,000
	Sodium Permanganate (20% Liq Soln)	$15,000
	Solids Thickening Polymer	$30,000
	Subtotal	$149,000
3	Materials and Supplies	
	Repair and Maintenance-Water Treatment	$200,000
	Office Supplies and Equipment	$30,000
	Uniforms	$15,000
	UV Usage	$33,945
	GAC Replacement	$485,000
	Laboratory Fees	$40,000
	Heavy Equipment Yearly Fees/Maintenance	$50,000
	Training	$20,000
	Miscellaneous	$50,000
	Other	$50,000
	Subtotal	$973,945
4	Electric Power	$500,000
	Subtotal	$500,000
5	Waste Solids Treatment and Disposal	
	Solids Disposal	
	Laboratory Fees	$25,000
	Transportation	$30,440
	Tipping Fee, $26.25/ton + tax	$111,440
	Subtotal	$166,880
TOTAL ANNUAL O&M COST		$2,965,825
Cost per million gallons		$1,311

MRC Water Treatment
Annual Operations and Maintenance Cost Estimate
Personnel

ITEM 1 PERSONNEL	Current (2004) Estimate Number	Annual Salary w/ Benefits [1]
Day Shift		
Administration Department		
Plant Superintendant	1	$82,000.00
Administrative Assistant [2]	1	$37,200.00
Safety Officer [2]	0.25	$50,000.00
Operations Department		
Plant Operator, Grade IV [3]	2	$63,400.00
Operator [3, 4]	5	$55,000.00
Laboratory Technician [2]	1	$60,000.00
Maintenance Department		
Maintenance [3]	4	$67,400.00
Instrumentation Technician [2]	1	$76,300.00
Total Day Personnel	15.25	
Night Shift		
Operations Department		
Plant Operator, Grade IV [3]	2	$63,400
Operator [3]	2	$55,000
Total Night Personnel	4	
Totals		
Day Costs	$939,400	
Night Costs	$236,800	
Annual Cost	$1,176,200	

NOTES:

[1] Salaries provided by City of Santa Fe

[2] Only one person for these positions, 8 hour shift. Other staff works 12 hour shifts.

[3] Number indicated is to cover all shifts per week

[4] One operator dedicated to sludge handling

MRC Water Treatment
Annual Operations and Maintenance Cost Estimate
Chemicals

ITEM 2 CHEMICALS	
Cationic Polymer (8105)	
Average Dose, mg/l	1.00
Use, lb/Mgal	8.3
Cost, $/lb	0.75
Cost, $/Mgal	6.26
Ferric Chloride	
Average Dose, mg/l	21.00
Use, lb/Mgal	175.1
Cost, $/lb	0.11
Cost, $/Mgal	19.27
Filter Aid Polymer	
Average Dose, mg/l	0.25
Use, lb/Mgal	2.1
Cost, $/lb	1.60
Cost, $/Mgal	3.34
Hydrofluosilicic Acid (23% Liq Soln)	
Average Dose, mg/l	1.00
Use, lb/Mgal	8.3
Cost, $/lb	0.16
Cost, $/Mgal	1.33
Nonionic Polymer (8181)	
Average Dose, mg/l	0.50
Use, lb/Mgal	4.2
Cost, $/lb	1.60
Cost, $/Mgal	6.67
Polyaluminum Chloride (PAX-18)	
Average Dose, mg/l	7.00
Use, lb/Mgal	58.4
Cost, $/lb	0.18
Cost, $/Mgal	10.65
Salt (for MIOX)	
Average Dose, mg/l	2.20
Use, lb/Mgal	77.1
Cost, $/lb	0.10
Cost, $/Mgal	7.71
Caustic Soda (50% solution)	
Average Dose, mg/l	11.00
Use, lb/Mgal	91.7
Cost, $/lb	0.065
Cost, $/Mgal	5.96
Sodium Permanganate (20% Liq Soln)	
Average Dose, mg/l	1.00
Use, lb/Mgal	8.3
Cost, $/lb	0.81
Cost, $/Mgal	6.76
Solids Thickening Polymer	
Average Dose, mg/l	1.00
Use, lb/Mgal	8.3
Cost, $/lb	1.60
Cost, $/Mgal	13.34
Total, $/Mgal	81.29

MRC Water Treatment
Annual Operations and Maintenance Cost Estimate
Materials and Supplies

ITEM 3 MATERIALS AND SUPPLIES	
Repair and Maintenance-Water Treatment	$200,000
Office Supplies and Equipment	$30,000
Uniforms	$15,000
UV Usage UV Usage (due to Calgon patent, $0.015/1000 gal)	$33,945
GAC Replacement	$485,000
Laboratory Fees	$40,000
Heavy Equipment Yearly Fees/Maintenance	$50,000
Training	$20,000
Miscellaneous Allowance for required materials and supplies for water treatment not covered under other items	$50,000
Other Allowance for required materials and supplies not directly related to water treatment Incl. BLM lease fees	$50,000
Total	$973,945

MRC Water Treatment
Annual Operations and Maintenance Cost Estimate
Electrical

ITEM 4 ELECTRIC POWER		Notes
Unit power cost, $/kwh	0.070	
Rapid Mixers:		
Number of units in service	2	
Operating HP	7.5	
Operating kw	6	
Energy usage, kwh/Mgal	43.4	*Assume 24 hr constant operation
Flocculation		
Number of trains, total	3	
Number of trains, in service	3	
Number of stages	3	
1st stage HP	4	
2nd stage HP	2.5	
3rd stage HP	1	
1st stage kw	3	
2nd stage kw	1.9	
3rd stage kw	0.7	
Power usage, kwh/Mgal	21.7	*Assume 24 hr constant operation
Sludge Collector		
Number of collectors	3	
Operating HP	5	
Operating kw	3.7	
Power usage, kwh/Mgal	10.7	*Assume 6 hr/day operation
Filter Backwash Pumps		
Number of units in service	2	1 standby
Operating HP	120	
Operating kw	89.5	
Power usage, kwh/Mgal	28.9	*Assume 2 hr/day operation (1 pump only)
Air Scour Blower		
Number of blowers	2	1 standby
Operating HP	149.1	
Operating kw	400	
Power usage, kwh/Mgal	64.5	*Assume 1 hr/day operation (1 blower only)
Ferric Chloride Pumps		
Number of units in service	2	1 standby
Operating HP	1	
Operating kw	0.7	
Power usage, kwh/Mgal	2.7	*Assume 24 hr constant operation (1 pump only)
Caustic Soda Pumps		
Number of units in service	2	1 standby
Operating HP	1	
Operating kw	0.7	
Power usage, kwh/Mgal	2.7	*Assume 24 hr constant operation (1 pump only)
Polymer Feeders		
Number of units in service	8	1 standby for each of the 4 systems
Operating HP	1	
Operating kw	0.7	
Power usage, kwh/Mgal	10.8	*Assume 24 hr constant operation (4 pumps only

MRC Water Treatment
Annual Operations and Maintenance Cost Estimate
Electrical

ITEM 4 **ELECTRIC POWER**		Notes
Hydrofluosilicic Acid Pump		
Number of units in service	2	1 standby
Operating HP	1	
Operating kw	0.7	
Power usage, kwh/Mgal	2.7	*Assume 24 hr constant operation (1 pump only)
MIOX Generator		
Number of generators	4	1 standby
Operating HP	27	
Operating kw	20	
Power usage, kwh/Mgal	88.7	*Based upon 2.2 mg/L Cl dose at 6.2 mgd
UV Disinfection System		
Number of units in service	3	1 standby
Operating HP	139	
Operating kw	104	
Power usage, kwh/Mgal	402.6	*Assume 24 hr/day operation (1 unit only)
Decant Return Pump		
Number of units in service	2	
Operating HP	10	
Operating kw	7.5	
Power usage, kwh/Mgal	29.0	*Assume 24 hr constant operation (1 pump only)
Admin Building HVAC & Lighting		
Number of units in service	5500	
Operating HP	0.02	
Operating kw	0.015	
Power usage, kwh/Mgal	319.4	*Assume 24 hr constant operation
Process Building HVAC & Lighting		
Number of units in service	60000	
Operating HP	0.01	
Operating kw	0.007	
Power usage, kwh/Mgal	1625.8	*Assume 24 hr constant operation, assume cooling energy = heating energy
Misc. Yard Lighting, etc.		
Number of units in service	1	
Operating HP	67	
Operating kw	50	
Power usage, kwh/Mgal	96.8	*Assume 12 hr/day operation
Total Power Use, kwh/Mgal	3162.9	*Assume 15% contingency

MRC Water Treatment
Annual Operations and Maintenance Cost Estimate
Residuals

ITEM 5 WASTE SOLIDS TREATMENT AND DISPOSAL	
Waste Solids Generation (All)	
Average RW turbidity, NTU	47.6
Average TOC precipitated, mg/l	5.7
Average DOC biologically removed, mg/l	1.0
Total from raw water solids, lb/Mgal	506.3
Ferric chloride dose, mg/l	21.0
From ferric, lb/Mgal	88.5
Polymer dose, mg/l	1.75
From polymer, lb/Mgal	14.6
Total, lb/Mgal	2121.1
Total, mg/l	254.3
Waste Solids Dewatering (All)	
Thickened Solids, %	3.0%
Thickened Solids Flow, gal/Mgal	8477.5
Cake solids, %	60%
Cake generated, wet tons/Mgal	1.77
Dewatering polymer dose, lb/TDS	1
Dewatering polymer cost, $/lb	2.90
Polymer cost, $/Mgal	3.08
Waste Solids Disposal	
Cake transportation cost, $/wet ton	7.61
Cake transportation cost, $/Mgal	13.45
Cake disposal cost, $/wet ton	27.86
Cake disposal cost, $/Mgal	49.24

Total Disposal Cost	
Mgal per year	2263
Cake transportation cost, $/yr	$30,440
Cake disposal cost, $/yr	$111,440
Total Cost, $/yr	$141,880

CDM

CONSTRUCTION COST ESTIMATE SUMMARY

OWNER: CITY OF SANTA FE
PROJECT: BUCKMAN DIRECT DIVERSION MRC WTP
LOCATION: SANTA FE, NEW MEXICO

PREPARED BY: PA DAVIS/MD RYAN
DATE JANUARY 2005

ITEM NO.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	**SITE FACILITIES**				
	PERIMETER FENCE				
	8' FENCE - COLORED PVC COATING W/ RZR	3,300	LF	$15.00	$49,500
	GATES	1	LOT	$5,000	$5,000
	SECURITY SYSTEM	1	LOT	$25,000	$25,000
	LANDSCAPING				
	TREES - PINON	50	EA	$450.00	$22,500
	SEEDING	16	ACRE	$4,000	$64,000
	IRRIGATION (ALLOWANCE)	16	ACRE	$2,500	$40,000
	SITE PAVING				
	SITE AND ACCESS ROADS	180,000	SF	$2.25	$405,000
	MISCELLANEOUS PAVING	25,000	SF	$2.25	$56,250
	PARKING APPURTENANCES	1	LOT	$10,000	$10,000
	SITE LIGHTING	1	LOT	$50,000	$50,000
					$727,250
2	**ADMINISTRATION BUILDING**				
	BUILDING CONSTRUCTION	5,000	SF	$175.00	$875,000
	OFFICE FURNITURE & CASEWORK	1	LOT	$35,000	$35,000
	CONTROL ROOM ACCESSORIES	1	LOT	$25,000	$25,000
	LABORATORY FURNISHINGS	1	LOT	$50,000	$50,000
	MAINTENANCE ROOM CRANE	1	EA	$15,000	$15,000
	MAINTENANCE ROOM EQUIPMENT/TOOLS	1	LOT	$15,000	$15,000
	BREAK ROOM APPLIANCES	1	LOT	$5,000	$5,000
	CONFERENCE/TRAINING ROOM EQUIPMENT	1	LOT	$15,000	$15,000
	HVAC SYSTEMS	1	LOT	$150,000	$150,000
	SPRINKLER SYSTEM	5,000	SF	$2.54	$12,700
					$1,197,700
3	**PROCESS BASINS**				
	EARTHWORK	33,700	CY	$15.00	$505,500
	CONCRETE	6,000	CY	$425.00	$2,550,000
	COAGULATION EQUIPMENT	3	LOT	$125,000	$375,000
	COAGULATION PUMPING SYSTEMS	5	LOT	$30,000	$150,000
	FLOCCULATION EQUIPMENT	3	LOT	$75,000	$225,000
	SEDIMENTATION EQUIPMENT	3	LOT	$75,000	$225,000
	FILTER UNDERDRAINS & EQUIPMENT	6	LOT	$80,000	$480,000
	FILTER BLOWER SYSTEMS	6	LOT	$75,000	$450,000
	UV REACTOR EQUIPMENT	3	LOT	$100,000	$300,000
	PROCESS AREA COVER	40,800	SF	$22	$897,600
	PROCESS AREA ENCLOSURE	9,200	SF	$20	$184,000
	PIPING	1	LOT	$300,000	$300,000
	HVAC SYSTEMS	1	LOT	$150,000	$150,000
	ELECTRICAL	1	LOT	$250,000	$250,000
	MIEX FACILITY	1	LOT	$3,500,000	$3,500,000
					$10,542,100
4	**CLEARWELL RESERVOIR**				
	EARTHWORK	90,000	CY	$22.00	$1,980,000
	CONCRETE	10,000	CY	$475.00	$4,750,000
	PUMPS - BACKWASH 150 HP VERT TURB	2	EA	$100,000	$200,000
	PUMPS - HI SVC 50 HP VERT TURB	3	EA	$50,000	$150,000
	PUMPS - BOOSTER 175 HP VERT TURB	3	EA	$120,000	$360,000
	PUMPS - BOOSTER 400 HP VERT TURB	4	EA	$175,000	$700,000
	PIPING	1	LOT	$150,000	$150,000
	ELECTRICAL	1	LOT	$150,000	$150,000
					$8,440,000
5	**SOLIDS FACILITIES**				
	EQUALIZATION BASINS				
	EARTHWORK	2,000	CY	$35.00	$70,000
	CONCRETE	450	CY	$500.00	$225,000
	PIPING	1	LOT	$30,000	$30,000
	GRAVITY THICKENERS				
	EARTHWORK	1,100	CY	$35.00	$38,500
	CONCRETE	1,125	CY	$650.00	$731,250
	EQUIPMENT	3	LOT	$100,000	$300,000

CDM

CONSTRUCTION COST ESTIMATE SUMMARY

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LOCATION: SANTA FE, NEW MEXICO

PREPARED BY: PA DAVIS/MD RYAN
DATE JANUARY 2005

ITEM NO.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	PIPING	3	LOT	$30,000	$90,000
	ELECTRICAL	3	LOT	$40,000	$120,000
	FILTER TO WASTE EQUALIZATION BASIN				
	EARTHWORK	300	CY	$35.00	$10,500
	CONCRETE	150	CY	$650.00	$97,500
	STRUCTURE	625	SF	$35.00	$21,875
	PUMPS - 25 HP CENTRIFUGAL	2	EA	$25,000	$50,000
	PIPING	1	LOT	$45,000	$45,000
	ELECTRICAL	1	LOT	$40,000	$40,000
	MECHANICAL SEPARATION FACILITY	1	LOT	$2,000,000	$2,000,000
					$3,869,625
6	**DRYING LAGOONS**				
	LAGOONS				
	EARTHWORK	25,500	CY	$6.00	$153,000
	GUNITE LINING	32,513	SF	$7.50	$243,844
	GRAVEL BOTTOMS	114,750	SF	$2.00	$229,500
	PIPING	5	LOT	$35,000	$175,000
	PUMP STATION				
	EARTHWORK	1,400	CY	$35.00	$49,000
	CONCRETE	300	CY	$500.00	$150,000
	STRUCTURE	2,500	SF	$35.00	$87,500
	PUMPS - 50 HP VERTICAL TURBINE	3	EA	$50,000	$150,000
	PIPING	1	LOT	$75,000	$75,000
	ELECTRICAL	1	LOT	$75,000	$75,000
	SOLIDS HANDLING TRUCKS	2	EA	$80,000	$160,000
					$1,547,844
7	**CHEMICAL FACILITIES**				
	SULFURIC ACID SYSTEM				
	STORAGE TANK - 15,000 GAL	1	EA	$40,000	$40,000
	METERING PUMPS	2	EA	$10,000	$20,000
	PIPING	1	LOT	$30,000	$30,000
	FLOURIDE SYSTEM				
	STORAGE TANK - 12,000 GAL	1	EA	$12,000	$12,000
	METERING PUMPS	2	EA	$10,000	$20,000
	PIPING	1	LOT	$25,000	$25,000
	SODIUM HYDROXIDE				
	MIOX SYSTEM	2	EA	$75,000	$150,000
	METERING PUMPS	2	EA	$10,000	$20,000
	PIPING	1	LOT	$40,000	$40,000
	CATIONIC POLYMER (COAGULANT AID)				
	TOTES - BY CHEM MFR	1	EA	$0	$0
	POLYMER FEED UNITS	3	EA	$10,000	$30,000
	PIPING	1	LOT	$15,000	$15,000
	NONIONIC FLOC AID POLYMER				
	TOTES - BY CHEM MFR	1	EA	$0	$0
	POLYMER FEED UNITS	3	EA	$10,000	$30,000
	PIPING	1	LOT	$15,000	$15,000
	FILTER AID POLYMER				
	TOTES - BY CHEM MFR	1	EA	$0	$0
	POLYMER FEED UNITS	3	EA	$10,000	$30,000
	PIPING	1	LOT	$15,000	$15,000
	GRAVITY THICKENER POLYMER				
	TOTES - BY CHEM MFR	1	EA	$0	$0
	POLYMER FEED UNITS	3	EA	$10,000	$30,000
	PIPING	1	LOT	$15,000	$15,000
	PRIMARY COAGULANT(S)				
	STORAGE TANK - 12,000 GAL	3	EA	$12,000	$36,000
	METERING PUMPS	3	EA	$10,000	$30,000
	PIPING	1	LOT	$30,000	$30,000
	CHLORINE SYSTEM				
	MIOX SYSTEM	4	EA	$75,000	$300,000
	METERING PUMPS	4	EA	$10,000	$40,000
	PIPING	1	LOT	$40,000	$40,000
	SODIUM PERMANGANATE				
	TOTES BY SUPPLIER	0	EA	$0	$0

CDM

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PREPARED BY: PA DAVIS/MD RYAN
DATE JANUARY 2005

ITEM NO.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	METERING PUMPS	2	EA	$10,000	$20,000
	PIPING	1	LOT	$20,000	$20,000
	SPARE CHEMICAL SYSTEM				
	STORAGE TANK - 12,000 GAL	2	EA	$12,000	$24,000
	METERING PUMPS	3	EA	$10,000	$30,000
	PIPING	1	LOT	$20,000	$20,000
	FUTURE SYSTEM				
	SPACE ONLY - NO FACILITIES	1	EA	$0	$0
	STRUCTURE				
	CONCRETE	650	CY	$500.00	$325,000
	AREA COVER	10,500	SF	$35.00	$367,500
	ELECTRICAL ROOM - PLANT	2,100	SF	$175.00	$367,500
	OVERHEAD CRANE SYSTEM	1	EA	$20,000	$20,000
	PLANT FORKLIFT	1	EA	$25,000	$25,000
	SPRINKLER SYSTEM	12,600	SF	$3.79	$47,754
	HEATING & VENTILATING SYSTEMS	1	LOT	$125,000	$125,000
	CHEM FACILITY ELECTRICAL	1	LOT	$250,000	$250,000
					$2,654,754
8	**MISCELLANEOUS WORK ITEMS**				
	PAINTING & COATINGS	1	LOT	$270,000	$270,000
	SCADA SYSTEM	1	LOT	$500,000	$500,000
	PROCESS INSTRUMENTATION & CONTROL	1	LOT	$500,000	$500,000
	PLANT POWER FEED	1	LOT	$500,000	$500,000
	EMERGENCY GENERATOR (800 KW)	1	LOT	$300,000	$300,000
	FIRE PUMP SYSTEM	1	LOT	$250,000	$250,000
	SIGNAGE	1	LOT	$10,000	$10,000
					$2,330,000
		SUBTOTAL			$31,309,273
		SUBTOTAL W/ INFLATION SINCE 1/04 ESTIMATE		3.50%	$32,405,097
NOTES		MATERIAL ESCALATION		10.00%	$3,240,510
		SUBTOTAL			$35,645,607
		CONTINGENCY		20.00%	$7,129,121
		FIELD OFFICE OVERHEAD		10.00%	$3,564,561
		HOME OFFICE OVERHEAD		5.00%	$2,138,736
		TOTAL CONSTRUCTION COST			$48,478,026
		MARGIN		10.00%	$4,847,803
		SUBTOTAL			$53,325,828
		BUILDER'S ALL RISK INSURANCE		0.50%	$266,629
		GENERAL LIABILITY INSURANCE		1.00%	$533,258
		BOND		1.00%	$541,257
		TOTAL CONSTRUCTION			$54,666,973
		CHANGE ORDER ALLOWANCE		3.00%	$1,640,009
		TOTAL			$56,306,982
		NMGRT		7.56%	$4,258,216
		TOTAL W/ NMGRT			$60,565,197

Section 5
Recommendations

5.1 Recommendations for Additional Work

This report was prepared to provide information for the preliminary design of the MRC WTP. However, it is recommended that additional testing and evaluations be completed as part of the preliminary design of the MRC WTP. These recommendations were presented throughout this report and are summarized here.

- Review Concerned Citizens for Nuclear Safety reports to assess potential for LANL contaminants to enter Rio Grande and MRC WTP and complete additional modeling, data collection, process selection or monitoring planning as necessary
- Continue to monitor for nitrate in the river from upstream wastewater treatment plants to assess need for inclusion of nitrate removal and monitoring technologies
- Collect additional river samples for *Cryptosporidium* analyses to refine Bin Classification recommendation
- Conduct additional testing to adequately evaluate blending of the MRC WTP water and Buckman Well water with water from the City wells and Canyon Road WTP
- Conduct corrosion testing to assess need for corrosion inhibitor
- Evaluate need for a surge tank at MRC WTP as part of the booster station control strategy
- Complete additional jar testing and/or pilot testing of coagulation/flocculation process to optimize process for TOC removal, including the use of dual coagulants
- Complete additional jar testing and/or pilot testing to collect filtered water UV254 measurement for design of UV system
- Determine EBCT and change out frequency of GAC for various TOC removal efficiencies
- Send raw water to various equipment manufacturers to assess suitability and design requirements, may include PAC, membranes, ballasted flocculation and dissolved air flotation
- Perform jar testing and pilot testing of MIEX technology to fully compare with other TOC removal technologies
- Using additional data, evaluate TOC removal technologies to select the most cost-effective, robust, and flexible technology
- Evaluate sludge removal technologies and work with City staff to select best option

- Refine necessary reserve volume for Clearwell
- Verify suitability of using chlorine dioxide alone or in combination with sodium hypochlorite through piloting work and SDS testing
- Use water quality model to determine chlorine residuals and DBPs in the enlarged distribution system to verify chlorine dose for finished water and to determine if remote chlorination stations are necessary.
- Evaluate the need to enclose the process basins as a potential cost savings measure
- Discuss the use of Phoenix's planned GAC regeneration facilities as a potential cost savings measure

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